AUTOMOBILE ENGINEER

DESIGN · PRODUCTION · MATERIALS

Vol. 49 No. 1 JANUARY 1959 PRICE: 3s. 6d.

MIRROR IMAGE

THERE may be very little to choose between an FBC bearing and another kind, but a great many people—including many of the foremost engineers—do in fact choose FBC bearings because they give excellent service. FBC standard bearings are very good, FBC 'E specification' bearings are made to closer tolerances, are quieter running and give still greater reliability which is unmatched by any standard bearing.

FBC specials, evolved to meet customers' difficult conditions, have become famous for their performance in piston and jet engines on aircraft, and may be worth remembering when new transmission and other developments are on the drawing board.

FISCHER BEARINGS COMPANY LTD., WOLVERHAMPTON

FISCHER BEARINGS COMPANY LTD., AND TIMKEN-FISCHER STOCKISTS LTD., BIRMINGHAM, ARE BOTH SUBSIDIARIES OF BRITISH TIMKEN LTD.

CHANGING GEAR

10,000 TIMES

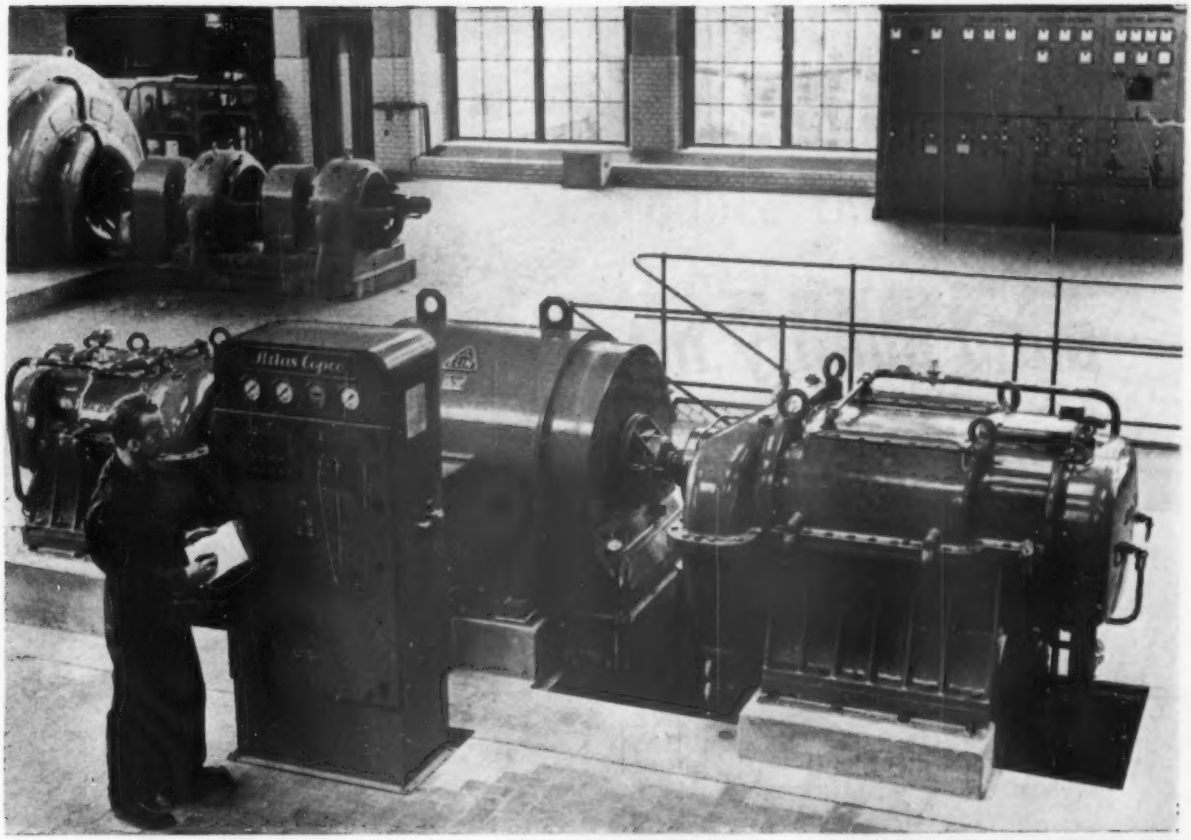
In the B.B.A. Research and Development Laboratories this machine tests Mintex clutch liners. In a routine test, two clutches on a common shaft are engaged and disengaged automatically every twelve seconds no less than ten thousand times. During this time the clutch plate accelerates up to 1,200 r.p.m.

Tests such as these are everyday routine in the B.B.A. laboratories and are carried out on both production samples and on new and experimental liners. They form part of the continual programme of research and development on which the Mintex reputation is securely based.

you can rely on

MINTEX

Mintex Brake and Clutch Liners are manufactured by British Belting & Asbestos Limited, Cleckheaton, Yorkshire, and are available from MINTEX Service Depots and Distributors throughout the country.



An Atlas Copco 'Twin-Air' rotary screw compressor (8,100 cfm) recently installed at the Grängesberg mine, central Sweden

Tested for two years in Arctic Circle iron mines

THE NEW 'TWIN-AIR' Rotary Screw Compressor

At Kiruna, in the arctic circle area of Northern Sweden, where the world's largest underground mine is being developed, Atlas Copco rotary screw compressors have been running under full operating conditions for two years.

Simple design, easy maintenance
The Atlas Copco 'Twin-Air' rotary screw compressor is technically simple with few moving parts. As there is no metallic contact between the compression components, need for overhauls are infrequent and little maintenance is necessary.

High efficiency
The high efficiency of the rotary screw compression system means reduced operating costs.

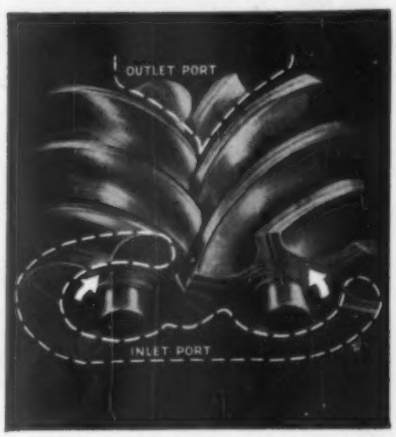
Lower installation costs
The 'Twin-Air' rotary screw compressor occupies less floor space than most other machines of equal capacity. This means marked savings in installation costs. Smaller high speed electric motors also contribute to initial cost saving.

Less sensitive to impure air
Free of any metallic contact between compression components, the rotary screw machine is less sensitive to impure air than any other design.

Oil-free air or gas
As no lubricant is necessary in the compression chamber, the rotary screw compressor delivers completely oil-free air or gas.

Smooth air flow
The design of the Atlas Copco 'Twin-Air' rotary screw compressor gives a smooth air flow. No 'surging' or 'pumping' characteristics.

Models up to 16,000 c.f.m.
The standard range of 'Twin-Air' screw compressors includes models up to 16,000 c.f.m. for pressures up to 115 p.s.i. Also available as vacuum pumps.



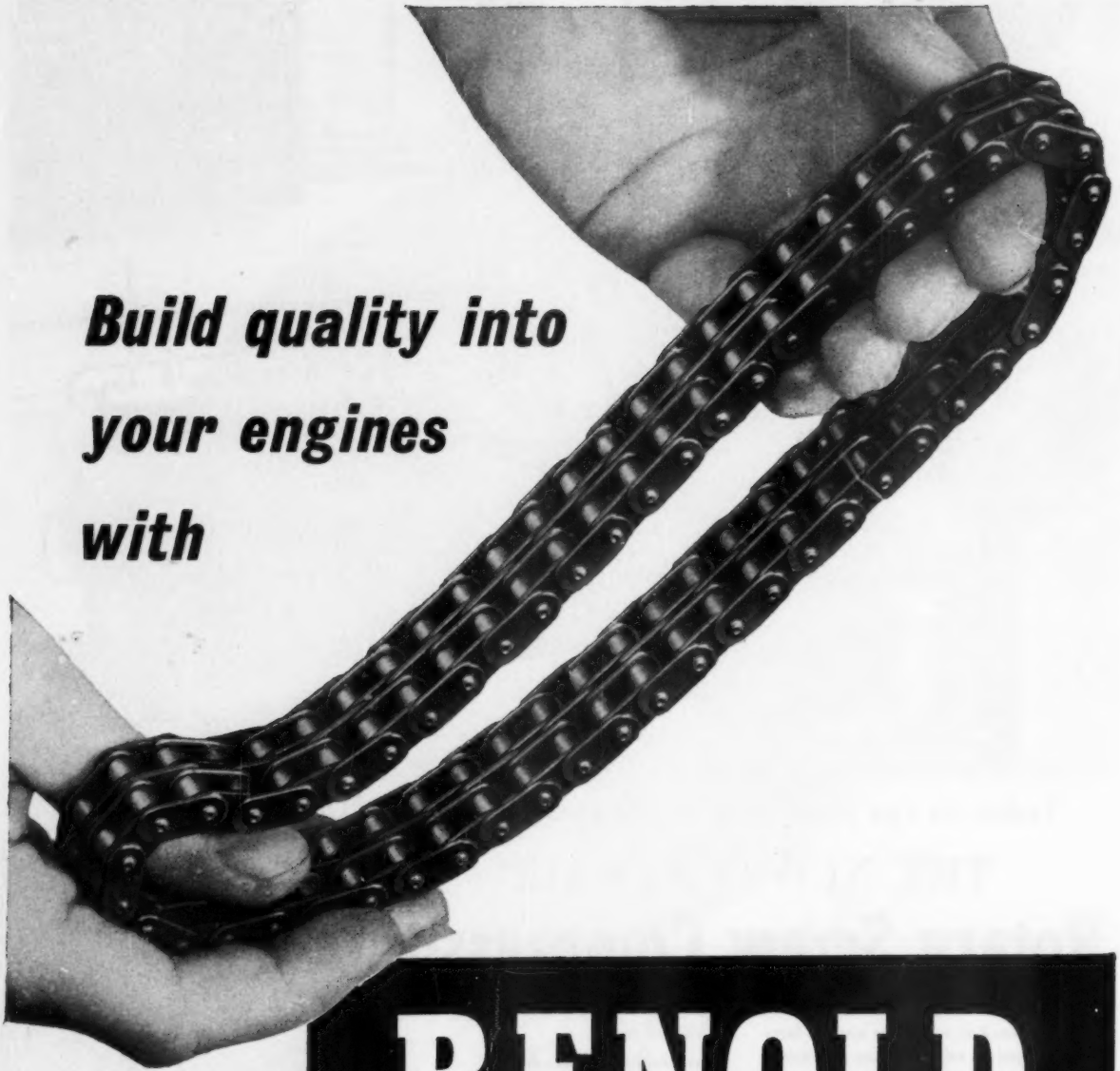
A pair of rotors with inlet and discharge ports indicated by the dotted lines.

A COMPLETE RANGE OF COMPRESSED AIR EQUIPMENT

Atlas Copco manufactures portable and stationary compressors, rock-drilling equipment, loaders, pneumatic tools and paint-spraying equipment. Sold and serviced by companies or agents in ninety countries throughout the world.

Atlas Copco PUTS COMPRESSED AIR TO WORK FOR THE WORLD

Contact your local company or agent or write to Atlas Copco AB, Stockholm 1, Sweden, or Atlas Copco (Great Britain) Limited, Beresford Avenue, Wembley, Middlesex
C.22*



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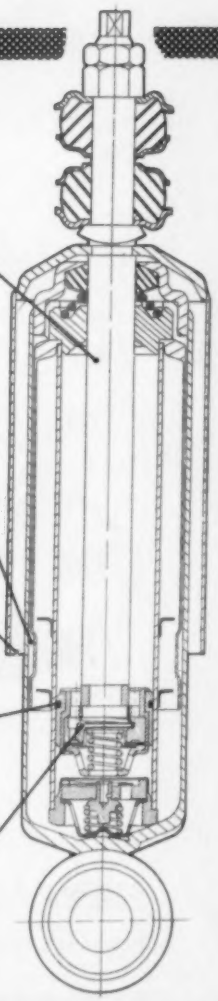

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with double baffles eliminates fade

COMPLETELY SEALED
for lifelong cleanliness

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No internal leaks however high the operating temperature

REBOUND VALVE
Coil Spring loaded shim valve ensures constant settings throughout life of damper

Here is a damper which sets a new standard of consistent efficiency throughout its long life—a damper which may be safely recommended.

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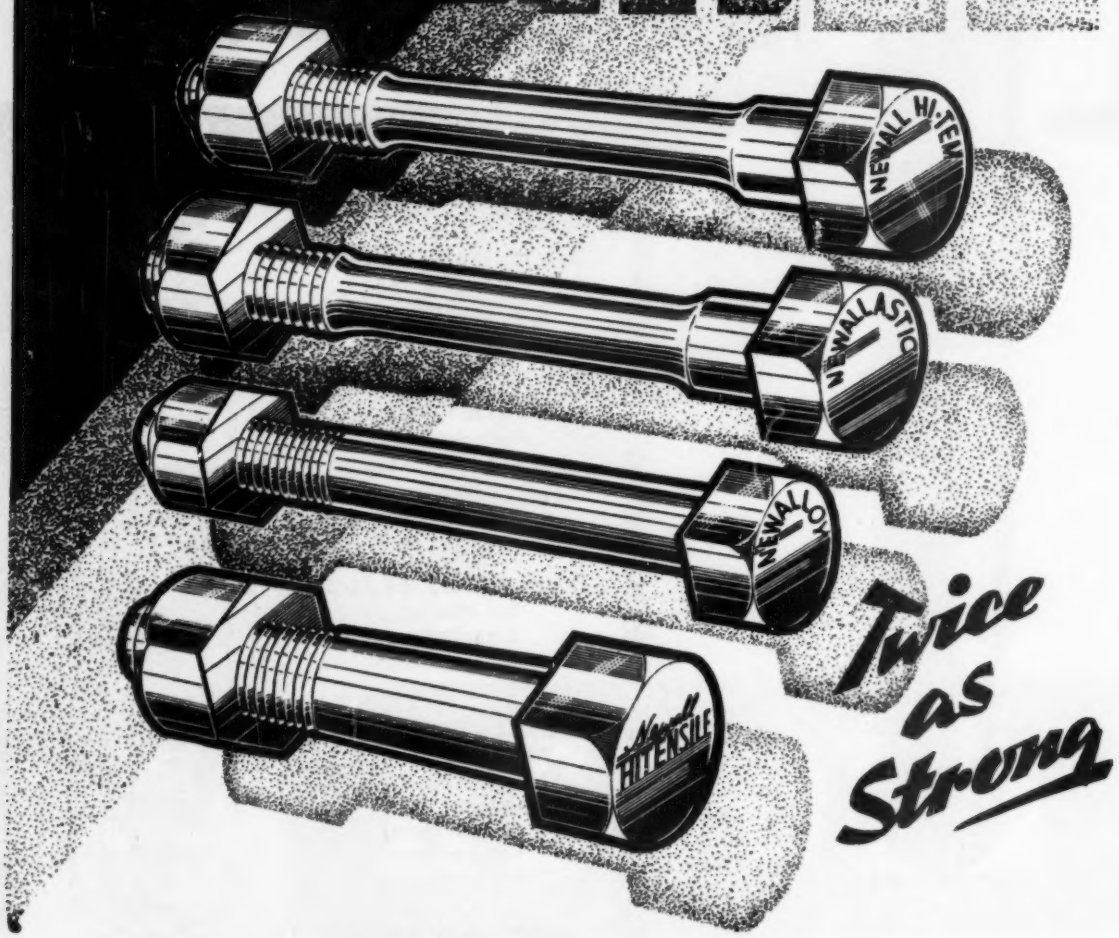

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are recognised by engineers as having unique qualities. We shall be happy to supply any engineer designer who is interested with details of the various bolts and studs, which cover the full range of modern requirements.

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Borg & Beck are concerned with the supply of nearly all the clutches in use on British vehicles: they have kept pace with design requirements and transmit a wide range of powers with great smoothness and durability.

There is a complete range of friction clutches available from 6¼" diameter to 18" diameter with torque capacities from 38 lb./ft. to 950 lb./ft.

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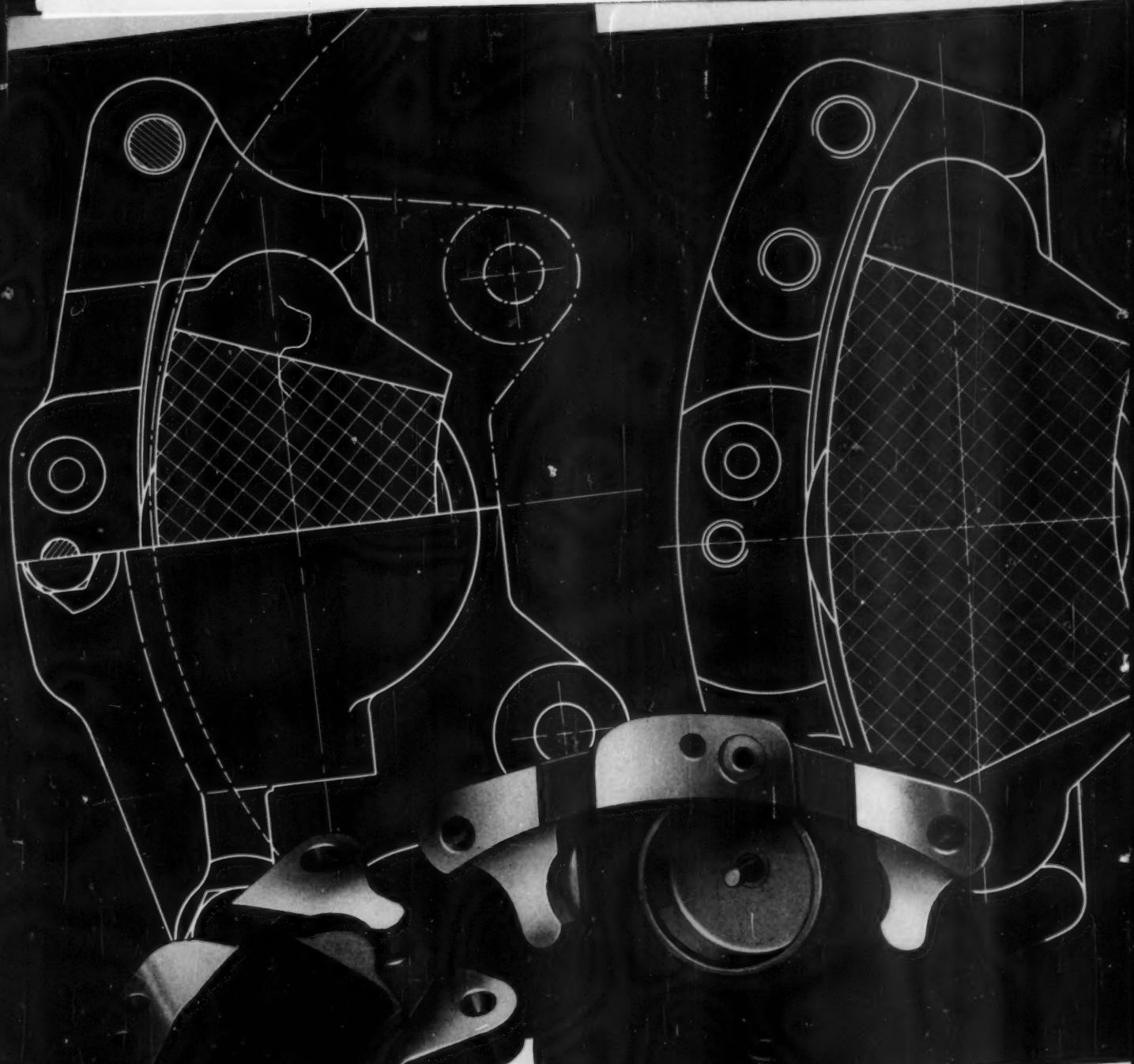


PATENTS PENDING

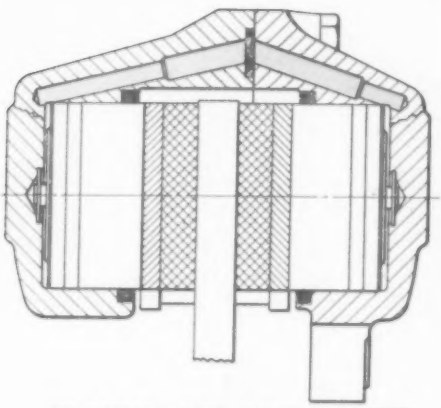
LOCKHEED HYDRAULIC BRAKE COMPANY LIMITED.

LOCKHEED *hydraulic* DISC BRAKES

The two sizes 'M' & 'H' cover practically every requirement, with ample sized friction pads that give normal mileage without replacement.

The view of the dismantled brake shows the 'M' type, for discs of 9½ to 11 in. diameter; the friction material is ⅜ in. thick, 5½ sq. in. area, as shown (full size) in the left-hand blue-print opposite.

The 'H' type is shown in the second blue-print (also full size) for discs 10 to 12 in. diameter, it has friction pads ½ in. thick and 7¼ sq. in. area.



INTERNAL FLUID DUCTING

GENERAL FEATURES.

Constant brake pedal travel throughout the life of the friction pads is provided by the automatic adjusters.

Friction pads are easily changed without disturbing the hydraulic connections.

Reserve of brake lining is clearly visible.

Two pistons; each has a simple and effective Lockheed seal.

Pistons are well-guided and excellent arrangements are made for excluding dirt, dust or water from the hydraulic equipment.

Internal fluid duct with one pressure seal, eliminates the outside pipe and also simplifies installation.

Servo-assistance is available if required, also hand brake mechanism.

LOCKHEED

Registered Trade Mark: LOCKHEED

The safest disc brake in the world

Our engineers would welcome the opportunity of discussing your future vehicle braking requirements.

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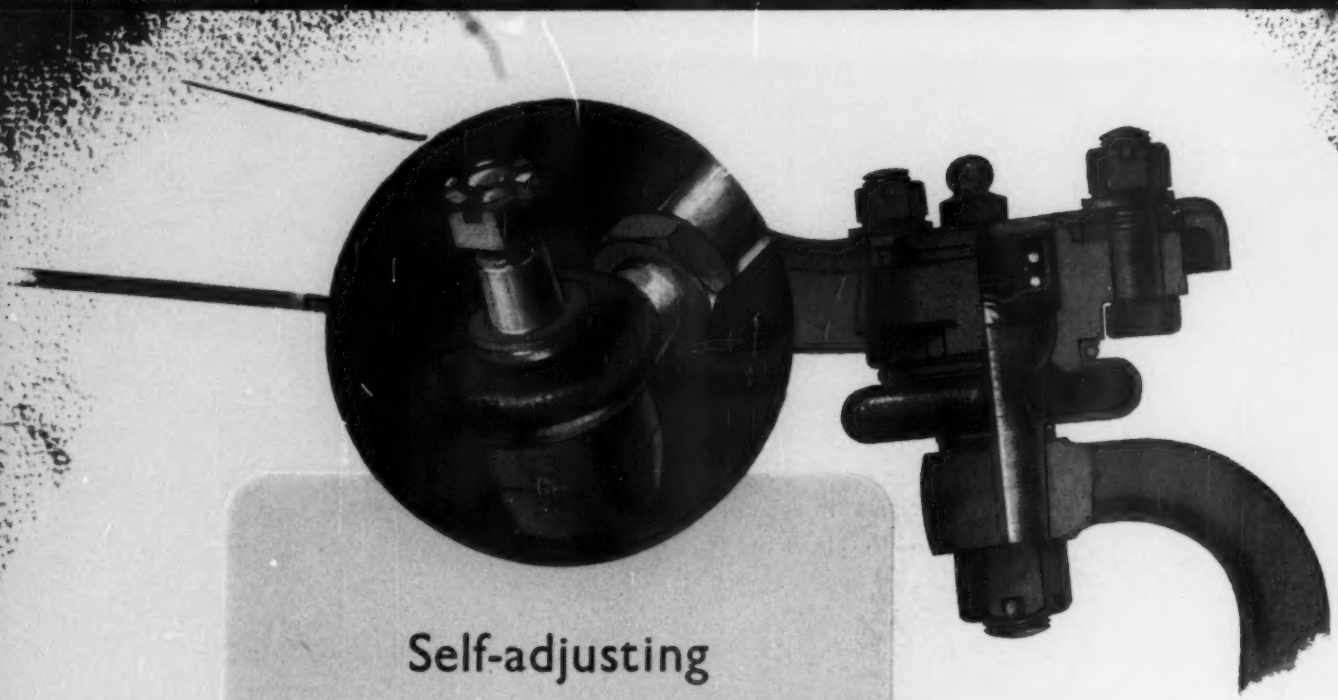
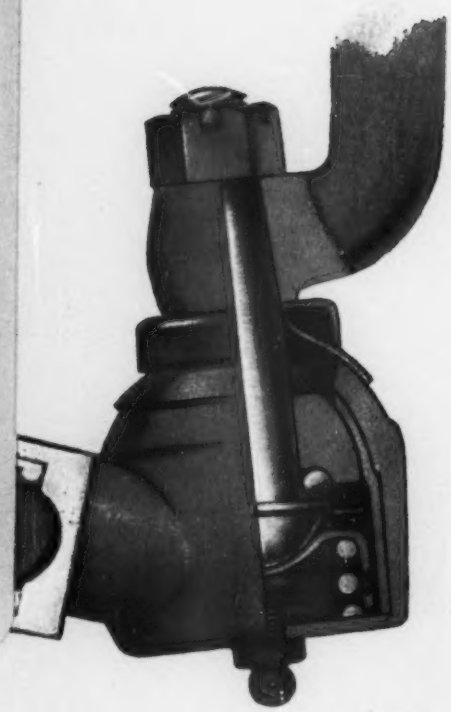


Self-adjusting

The Thompson self-adjusting ball-joint (above) eliminates dangerous backlash: friction is reduced, and construction simplified.

Thompson ball-joint suspension (at side) considerably simplifies the steering and suspension layout, facilitates assembly and overhaul and results in greater steering freedom. The upper joint is non-load-carrying and serves the double purpose of providing the second 'king-pin' bearing and the necessary articulation for the suspension linkage.
Both joints are self-adjusting.



THOMPSON

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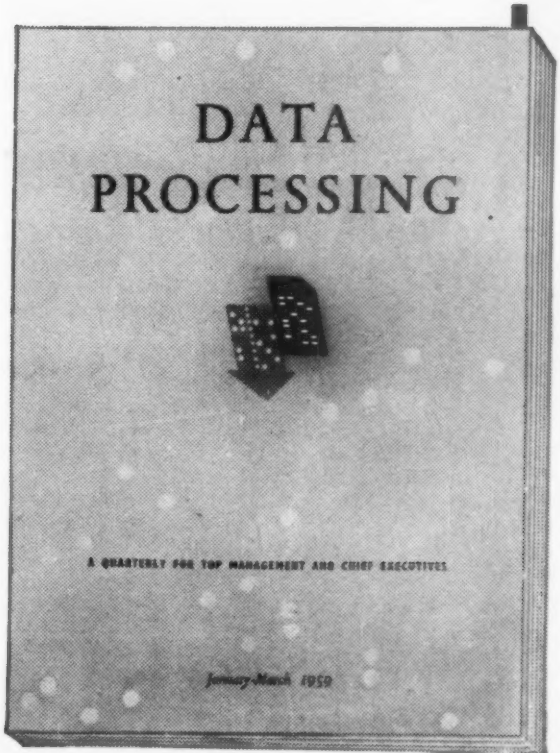
This new journal provides today the information which management must have for higher efficiency tomorrow

AUTOMATIC AIDS TO CONTROL, ADMINISTRATION AND ROUTINE WORK IN OFFICE AND FACTORY CAN BRING RICH REWARDS TO THOSE WHO FIRST APPLY THEM



Commercial and industrial concerns everywhere have warmly welcomed this authoritative guide to the choice of equipment and its correct application

As production becomes more automatic and research more exacting, new methods of handling industrial information are being evolved. Applications of these fresh methods throughout industry will significantly improve efficiency, increase output, reduce costs.

Every day, more and more progressive organizations—at home and abroad—are subscribing to DATA PROCESSING, the new Iliffe quarterly which describes the means by which this can be achieved. The whole range of automatic aids—computers, punched-card machinery and allied equipment—is examined and the best of the current operational practices presented in a form readily applicable to particular problems. Completion of the order below is the first move in ensuring that your organization is early among those who benefit from these new methods.

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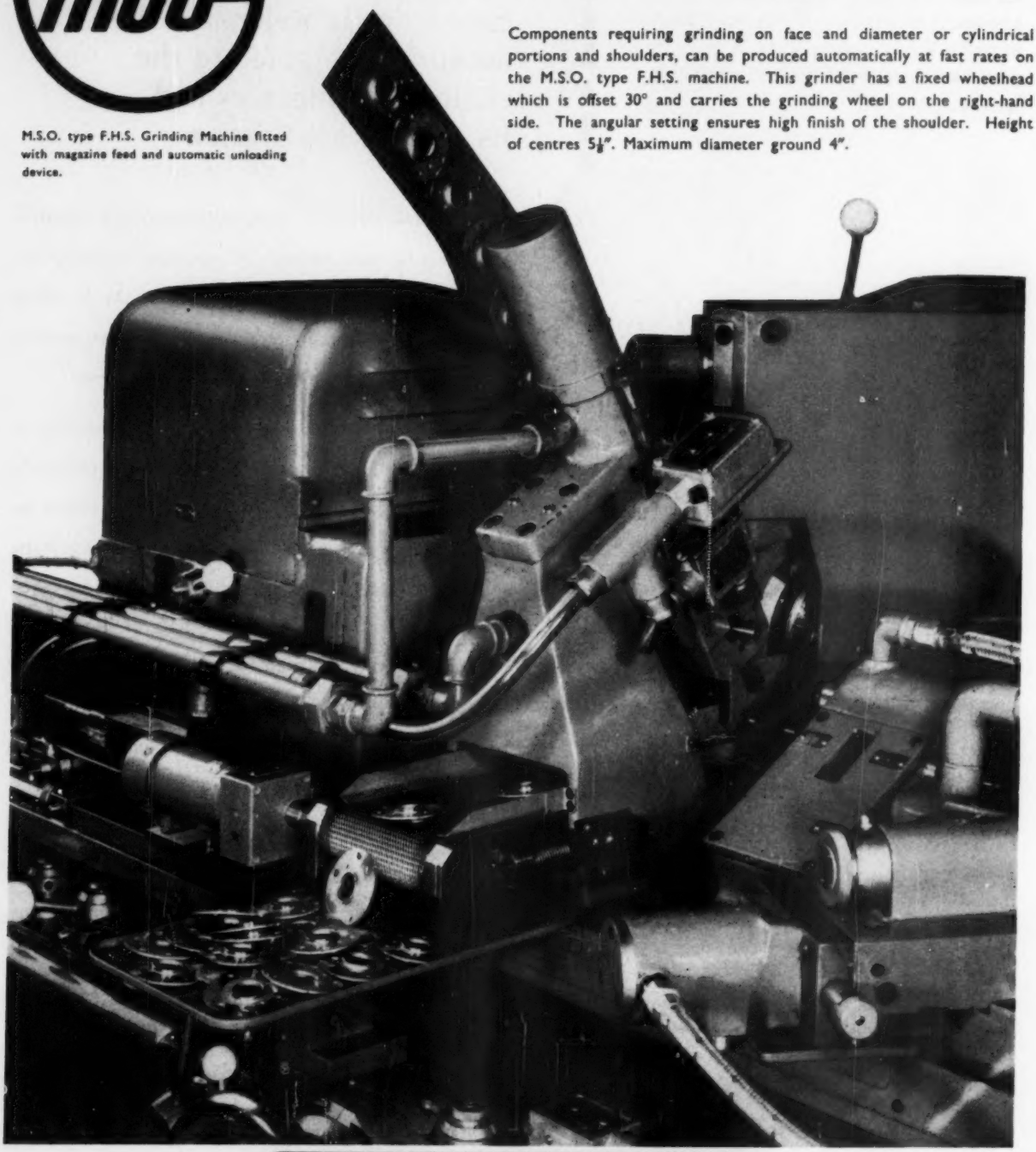
M.S.O. type F.H.S. Grinding Machine fitted with magazine feed and automatic unloading device.



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The Maxipilot is made with 20 in. or 32 in. between centres and maximum swing 16 in. over bed; 9 in. over the cross slide. Write today for full details.

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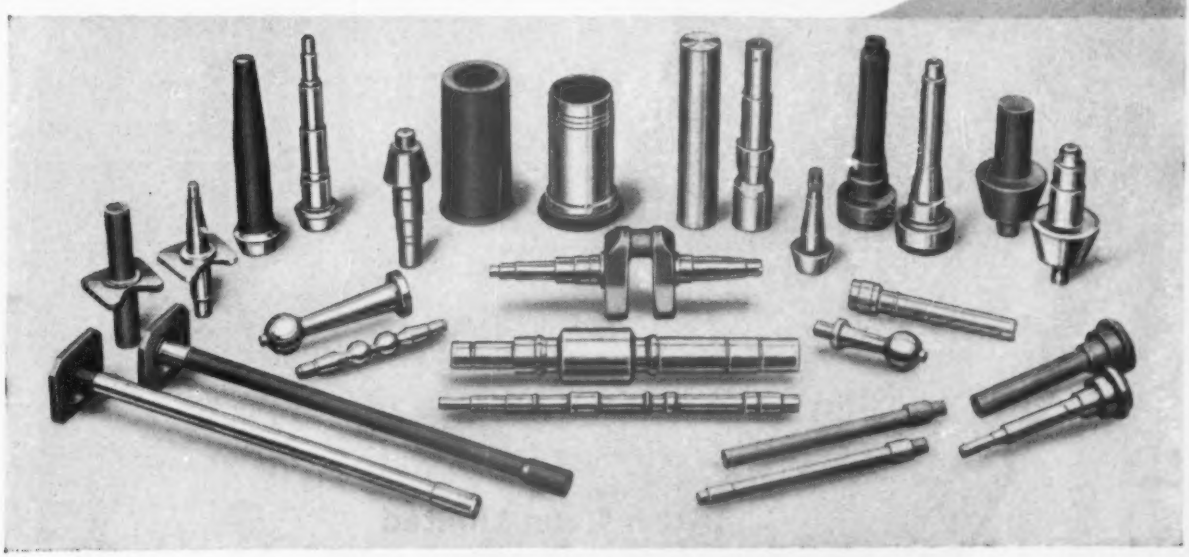

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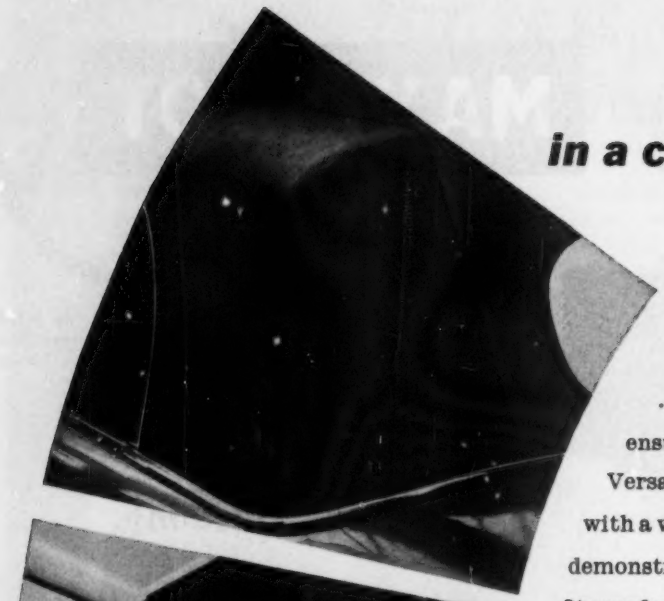

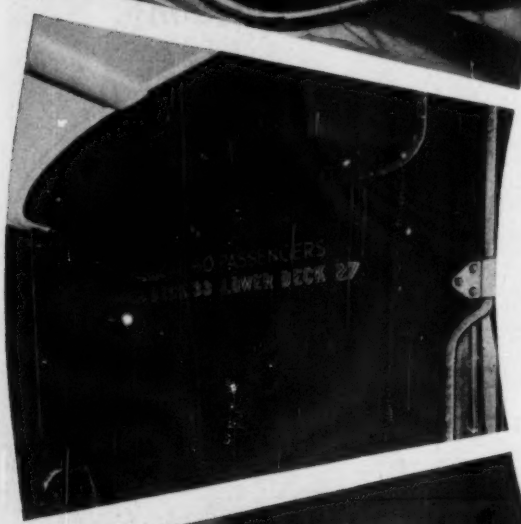

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The illustrations show three uses of Everflex leathercloth made by Bernard Wardle (Everflex Ltd) with Geon PVC.

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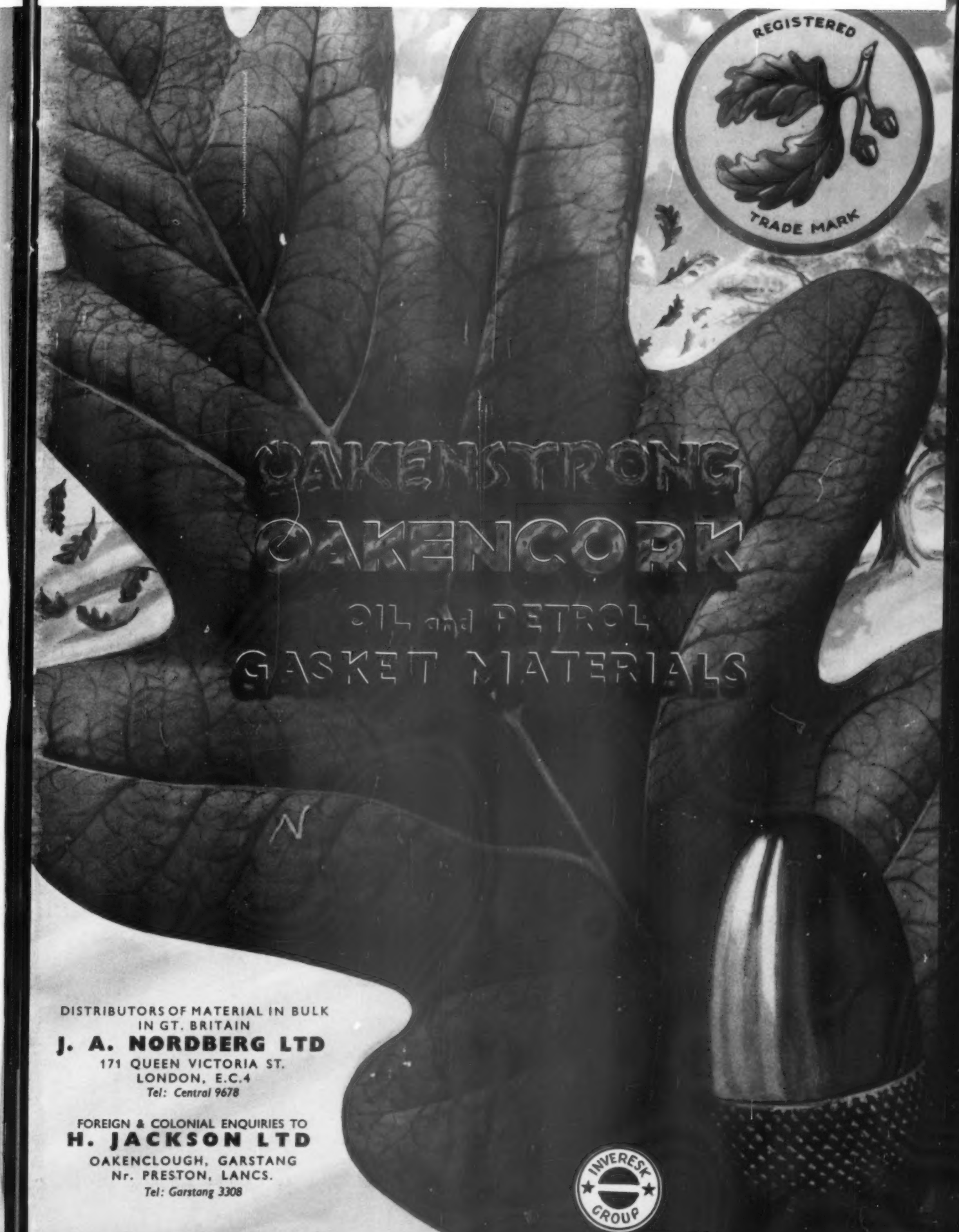
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Gives the Finishing Touch.
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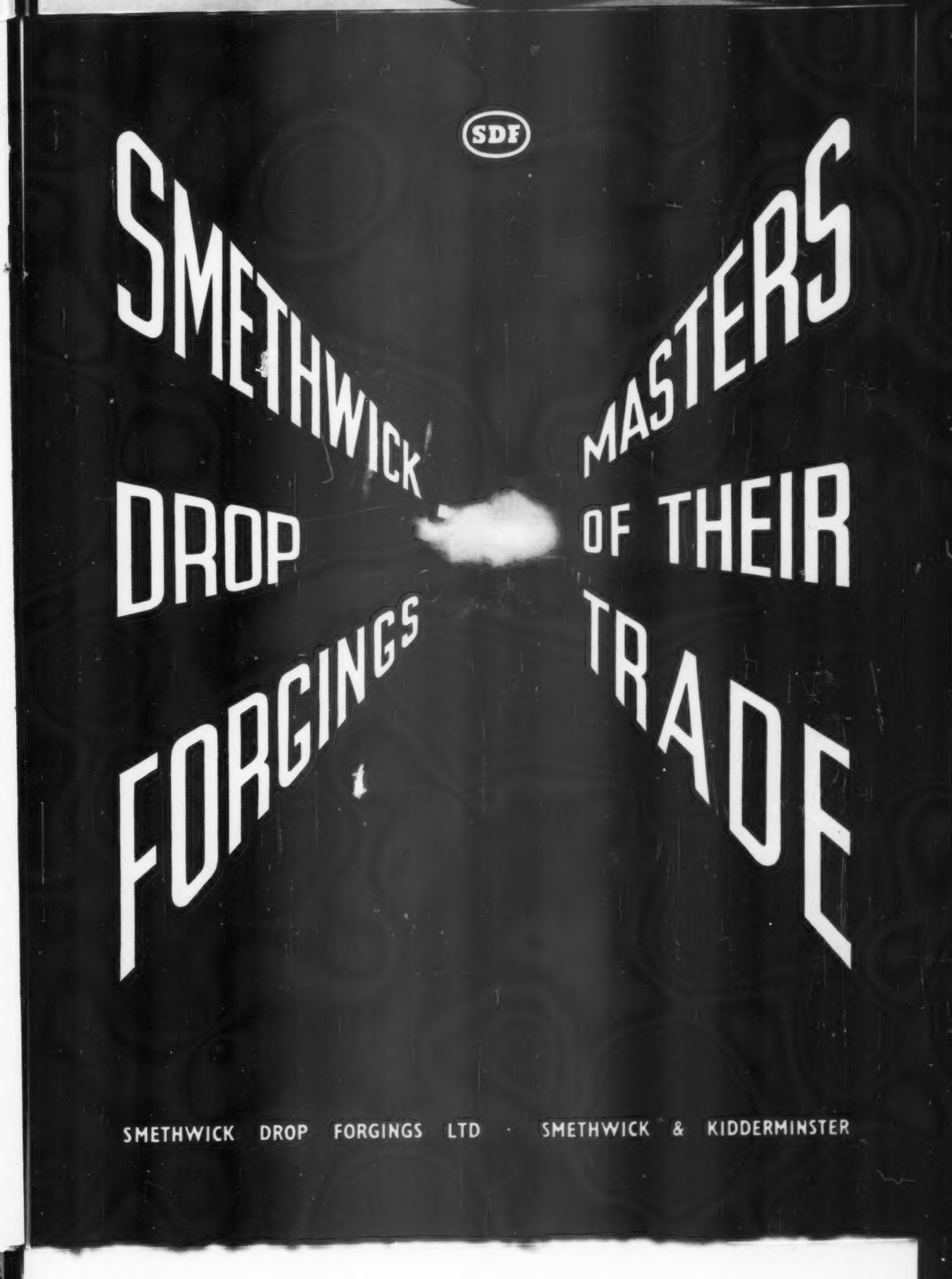
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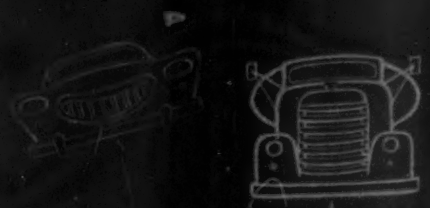
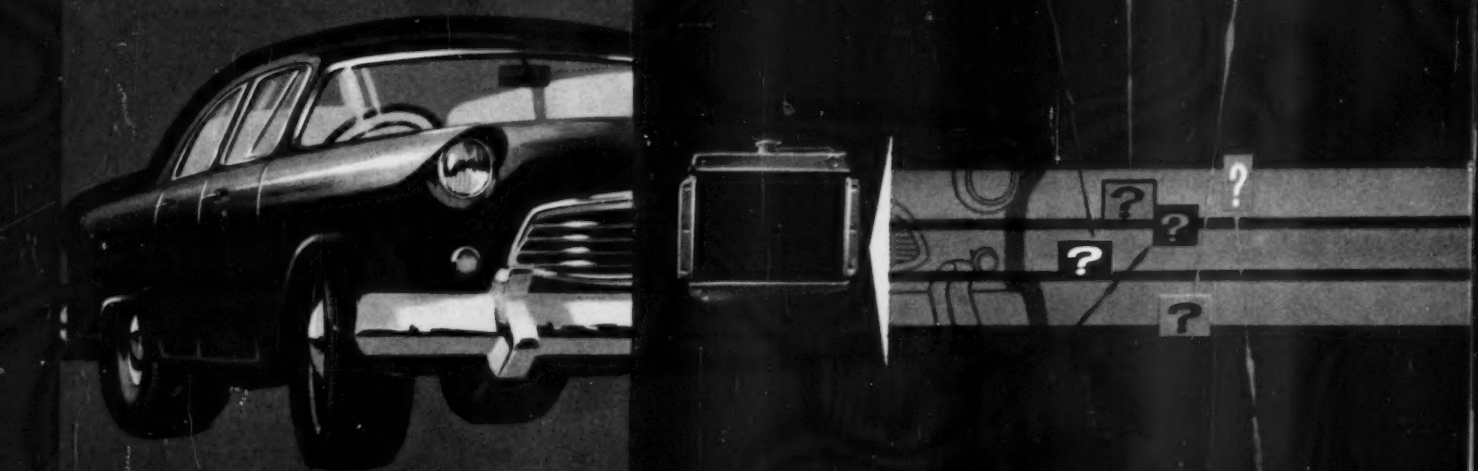


cooling problems get a warm welcome



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Obviously

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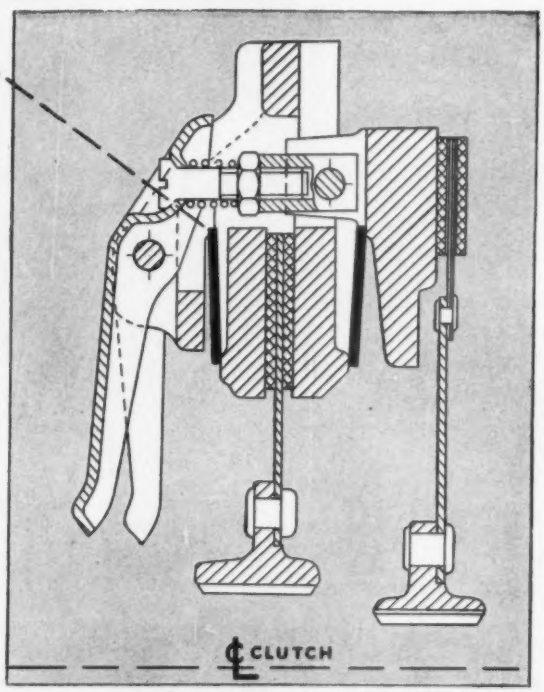

By courtesy of Massey-Harris-Ferguson (Great Britain) Ltd.

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The Belleville Washer clutch assembly is one of the many outstanding features which make the Massey-Ferguson 35 Tractor so deservedly popular.

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- ★ *This means longer life for the clutch and reduced maintenance costs.*
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- ★ *Take-off gear can be operated while the tractor is in motion.*

Belleville Washers solve many a tricky problem where shock or sustained load is excessive and movement must be slight. Engineers turn to Salter for these springs that

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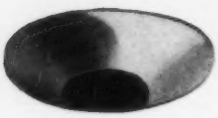
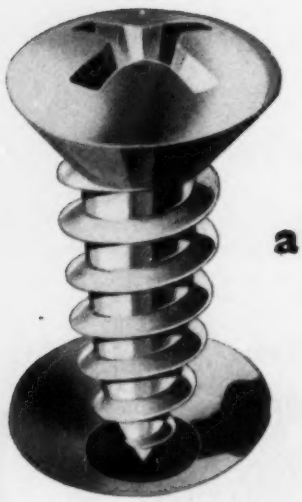
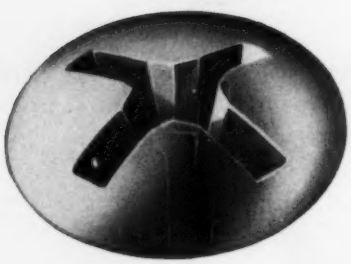


a plain



advantage

With steadily-rising labour costs, every non-essential operation along the production line assumes increasing significance. One of these recurring operations has been the precision thread-cutting of screw holes, which, in assembly, have (equally precisely) to be registered together. But the tapping, self-locating screw eliminates all this, and permits assembly by less-skilled labour. And the cross-recessed head version is designed for use with power-drivers—without a scratch of damage to worker or job. The tapping screw is demonstrably quicker—cheaper—stronger—safer than the conventional machine screw. Such plain advantages pay such handsome dividends!



in tapping screws

Linread

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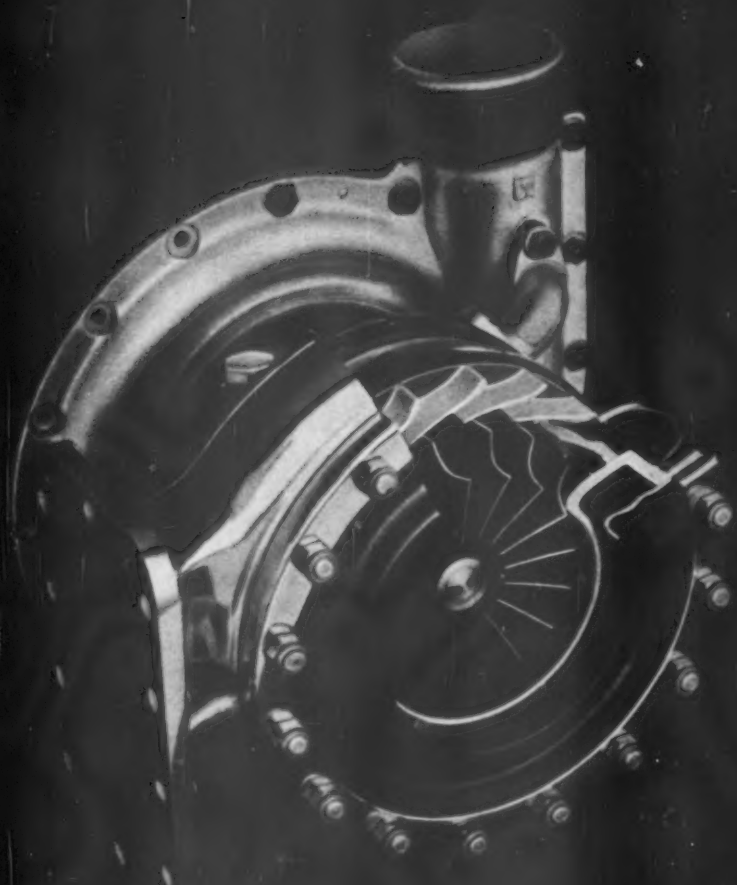

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life for the Auto Engineer is not always placid, but the continued research of Midcyl helps smooth out such of his problems as are associated with Cylinder Blocks, Cylinder Heads, Camshafts and Brake Drums

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Half of the crankcase
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precision forged in Hiduminium R.R.58.

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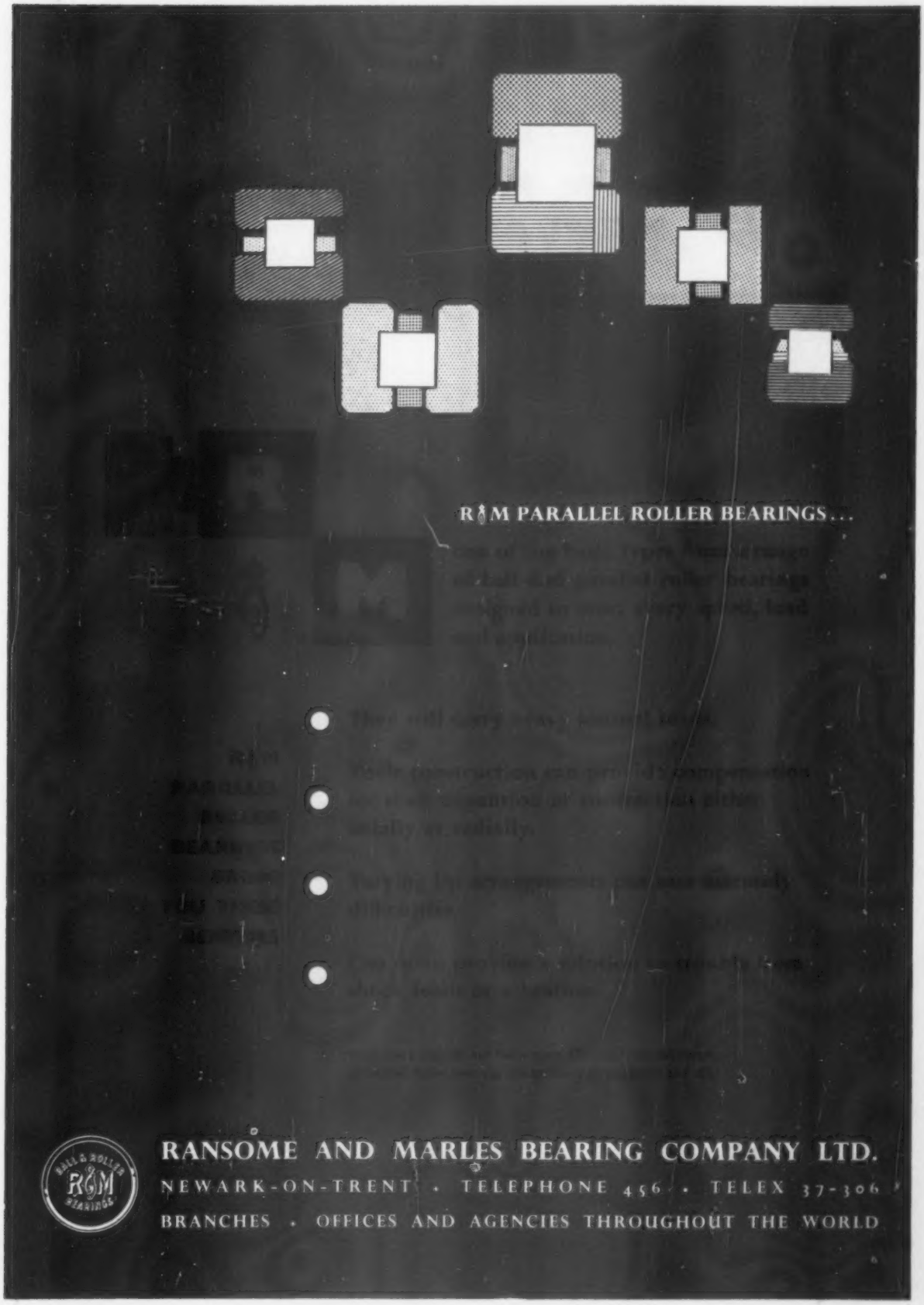
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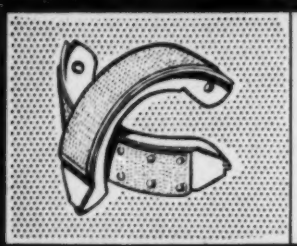
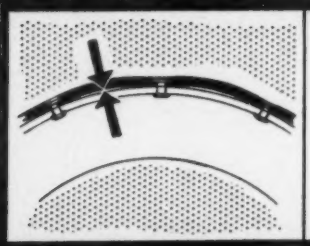
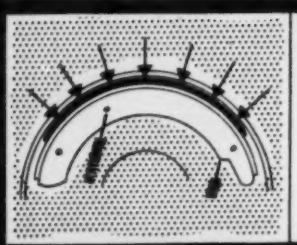


2 They are correctly riveted or bonded and precision ground to specified contours



5 They ensure that the lining fits tight to the shoe platform and so avoids this kind of gapping



3 They bed down quickly to full contact area and give highest efficiency braking in minimum time

6 They are your assurance that your vehicle braking is as good as new

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GIRLING FACTORY LINED REPLACEMENT BRAKE SHOES

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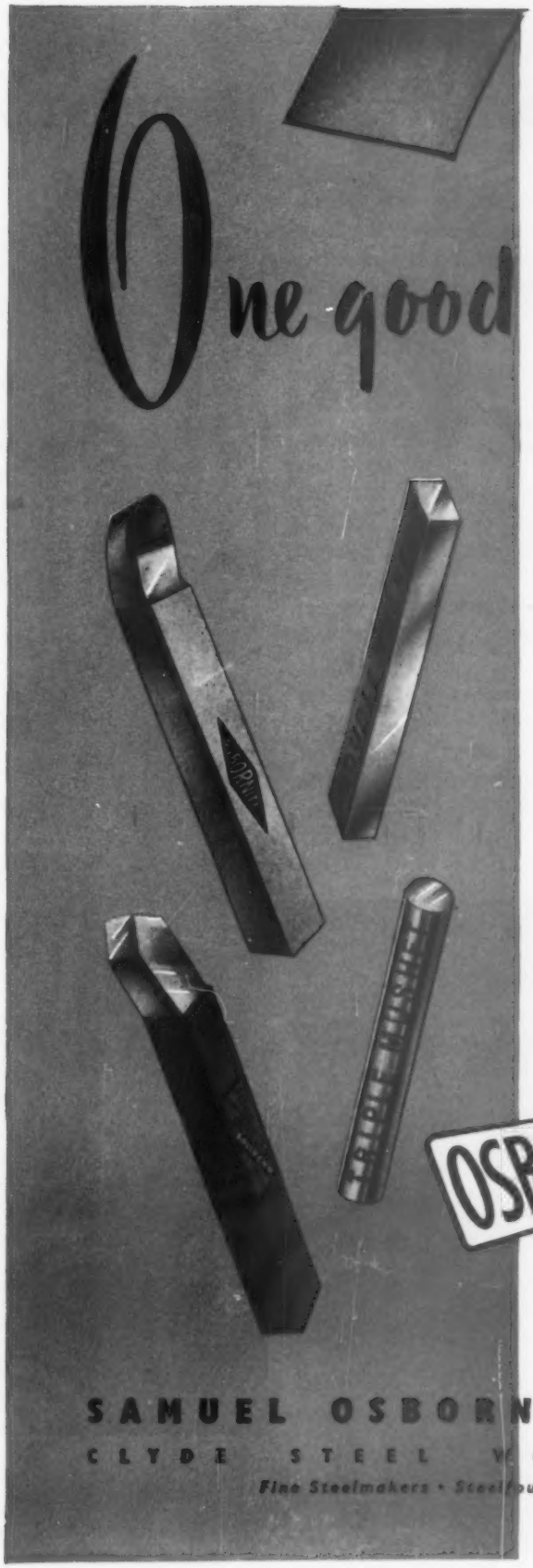
One good turn..



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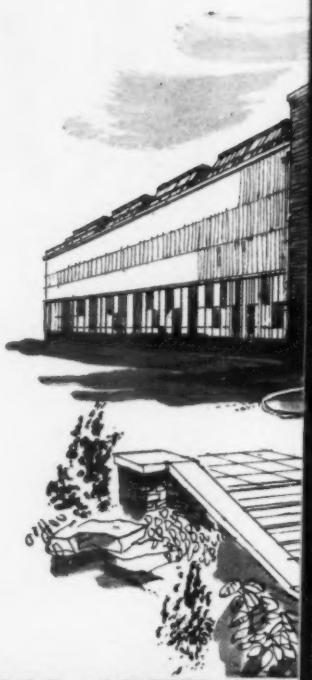
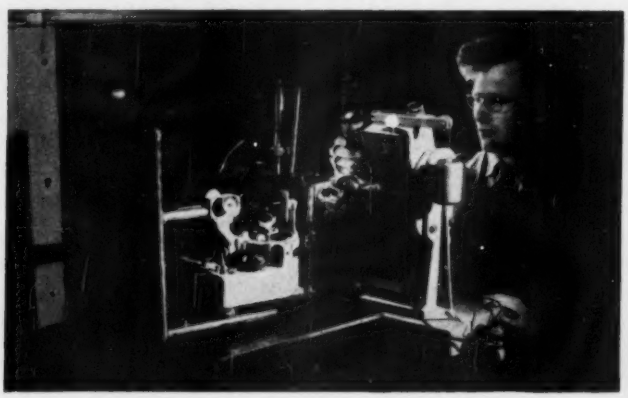
Nowhere in the world is so much scientific effort concentrated on the study of friction phenomena and the development of improved friction materials for brake and clutch linings.

A group of physicists, for instance, is probing the basic question—"What is surface friction?". A complete answer to it will revolutionise the whole approach to brake lining manufacture. Ferodo chemists are making significant original contributions to the world's knowledge of the structure of chrysotile asbestos, the heat resistant fibrous mineral which is the basis of conventional brake linings.

Facilities for such fundamental work are matched on the development side by the test house dynamometer machines and the test vehicles on which new materials are accurately assessed.

Since the days of its founder, Herbert Frood, it has been an industry based on research. Today the Ferodo Works is the largest single unit in the world making brake linings and clutch facings. The new Ferodo laboratories are its assurance that in the field of friction linings for drum brakes, for disc brakes, for whatever braking systems the future may hold—it will always be Ferodo First.





". . . original contributions to the world's knowledge of the structure of chrysotile asbestos."

Test house dynamometer machines.

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The new building contains chemical and physical laboratories, the test house and a garage for the fleet of test vehicles; an experimental production laboratory; drawing office, workshops, library, conference room and administrative offices.

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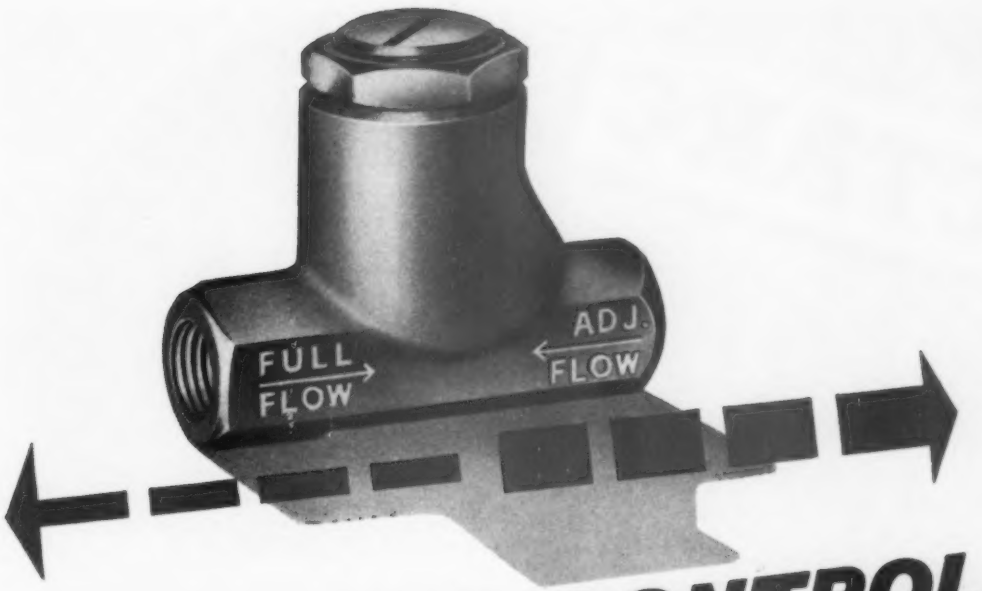

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SCHRADER FLOW CONTROL VALVES provide a control of movement speed so essential to the effective use of compressed air equipment. The range of valves has now been extended to give even greater flexibility.

The valve is easily set, by means of an adjustment screw, thus determining how fast the air flows in the "adjusted" direction. If used in conjunction with an air cylinder, for instance, the valve can control the pressure build-up and with it the *speed* of the piston thrust, but not its pushing force. This controlled thrust speed avoids the impact shock of suddenly applied air pressure, yet permits full thrust force. When the valve is operating in the "full flow" direction a poppet is opened, giving open line pressure. Where controlled air flow is required in both directions, two valves can be fitted back-to-back.

Although designed primarily for air control, these valves are equally suitable for use with oil or water in hydraulic systems.

Body of cast brass.
Non-corrodible plunger assembly, replaceable in one unit.
Substantial lock-nut resists vibration.

The $\frac{1}{8}$" bore valve is the latest addition to the Schrader range, which now covers $\frac{1}{8}$", $\frac{1}{4}$" and $\frac{3}{8}$" B.S.P. sizes. These provide a pressure range as follows:—AIR: 0-400 P.S.I. OIL or WATER: 0-800 P.S.I.

- LARGE POPPET TYPE PLUNGER PERMITS FAST, FULL RETURN FLOW.
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10

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HIGH range for plate welding . . 65 V at 50—310 A
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Rated to BSS 638/1953 for continuous duty at maximum current . Load 20 kVA

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A wide range of Actarc electrodes is available. There are lime-ferritic electrodes for welding medium carbon and low alloyed steel; mild steel electrodes for general purpose work; special rods for vertical and overhead welding, and for deep penetration; electrodes for fast horizontal production work; electrodes for boiler plate; non-ferrous electrodes for aluminium, nickel and bronze.

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Air and Oil cooled MEDIA transformers ...	Low Voltage range 65 V	50-310 A
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Oil cooled MASTA transformer	Low Voltage range 65 V	70-440 A
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Two easily selected infinitely variable current ranges.		
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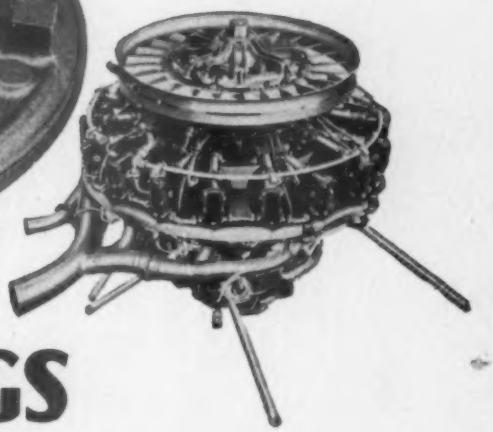
P 10

Alvis Leonides Engines



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Harpers make the clutch plate castings used in Alvis Leonides engines, widely installed in helicopters. High strength, soundness and freedom from distortion are essential, as these castings provide the means by which the power is transmitted from the engine to the rotor blades.

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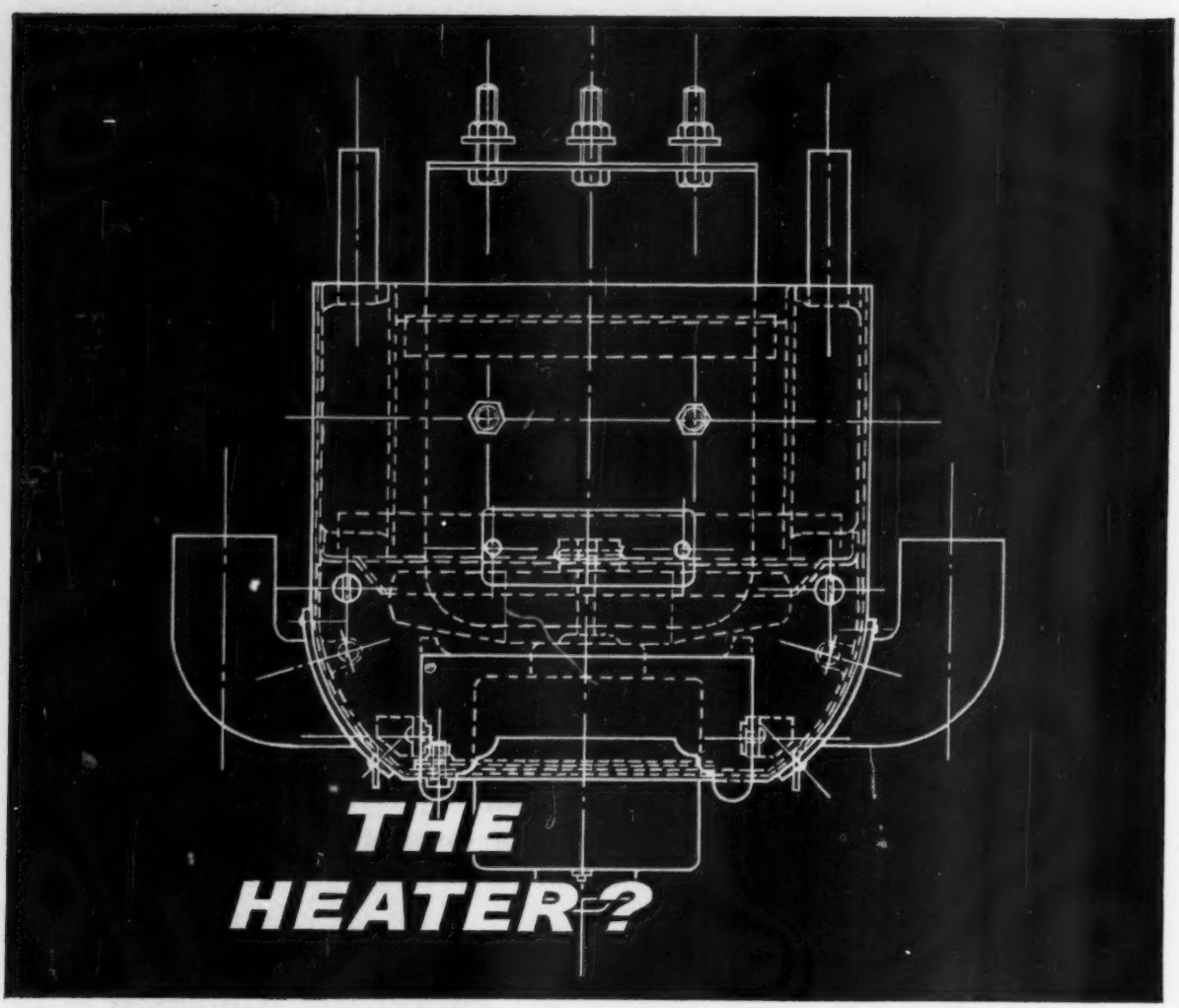

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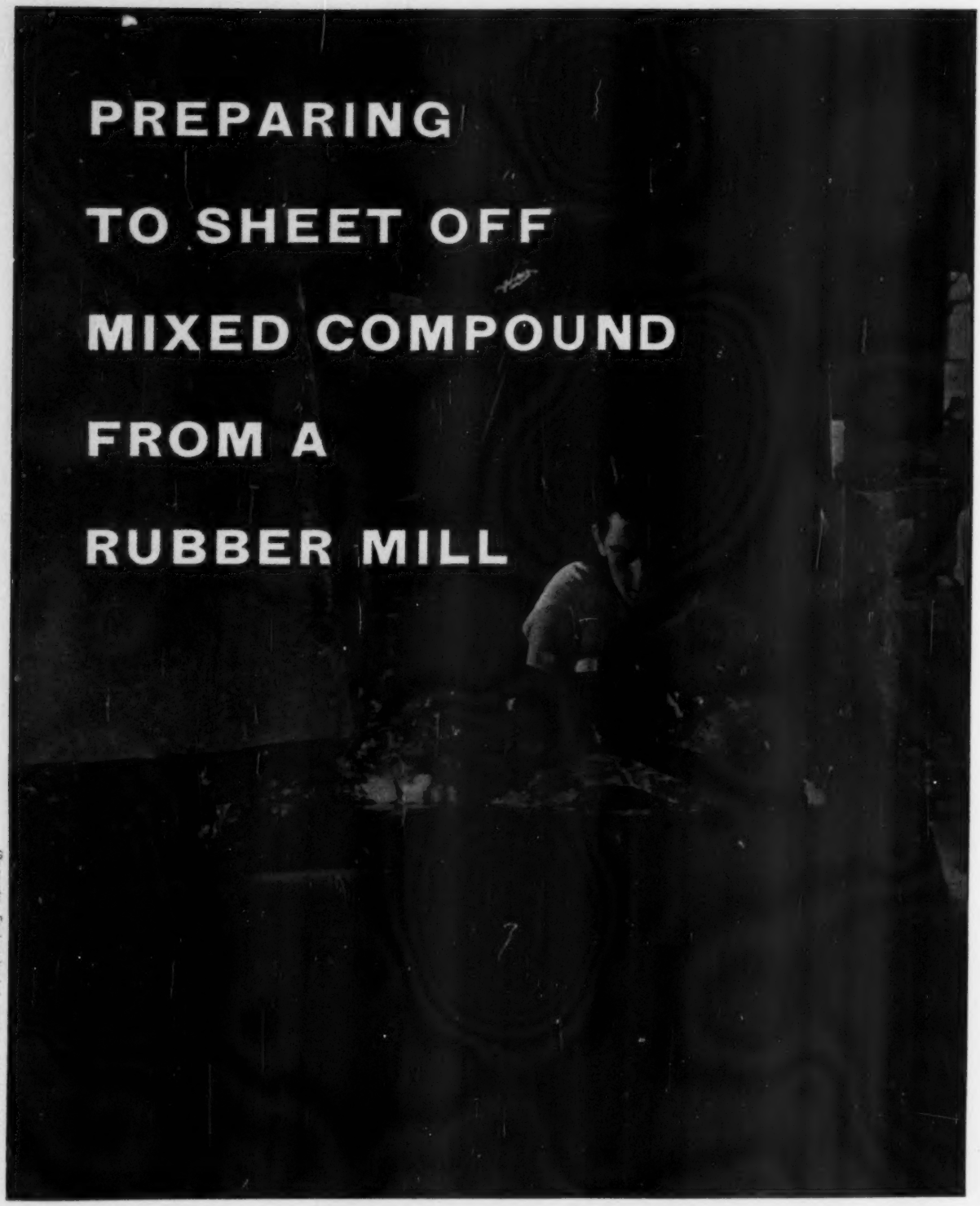

(By courtesy Engineering Ltd., photograph by Walter Nurnberg.)

Whilst this is an operation common to any rubber mill, our study seems particularly and happily to catch the spirit of EMPIRE RUBBER — RUBBER BONDERS. Over a ton of mix an hour is handled by this operator and here he is seen adding the sulphur to the mix. This requires a high degree of skill, for good dispersion is essential. The take-off conveyor behind him duly carries away the product of his work for cooling, slabbing and storing.

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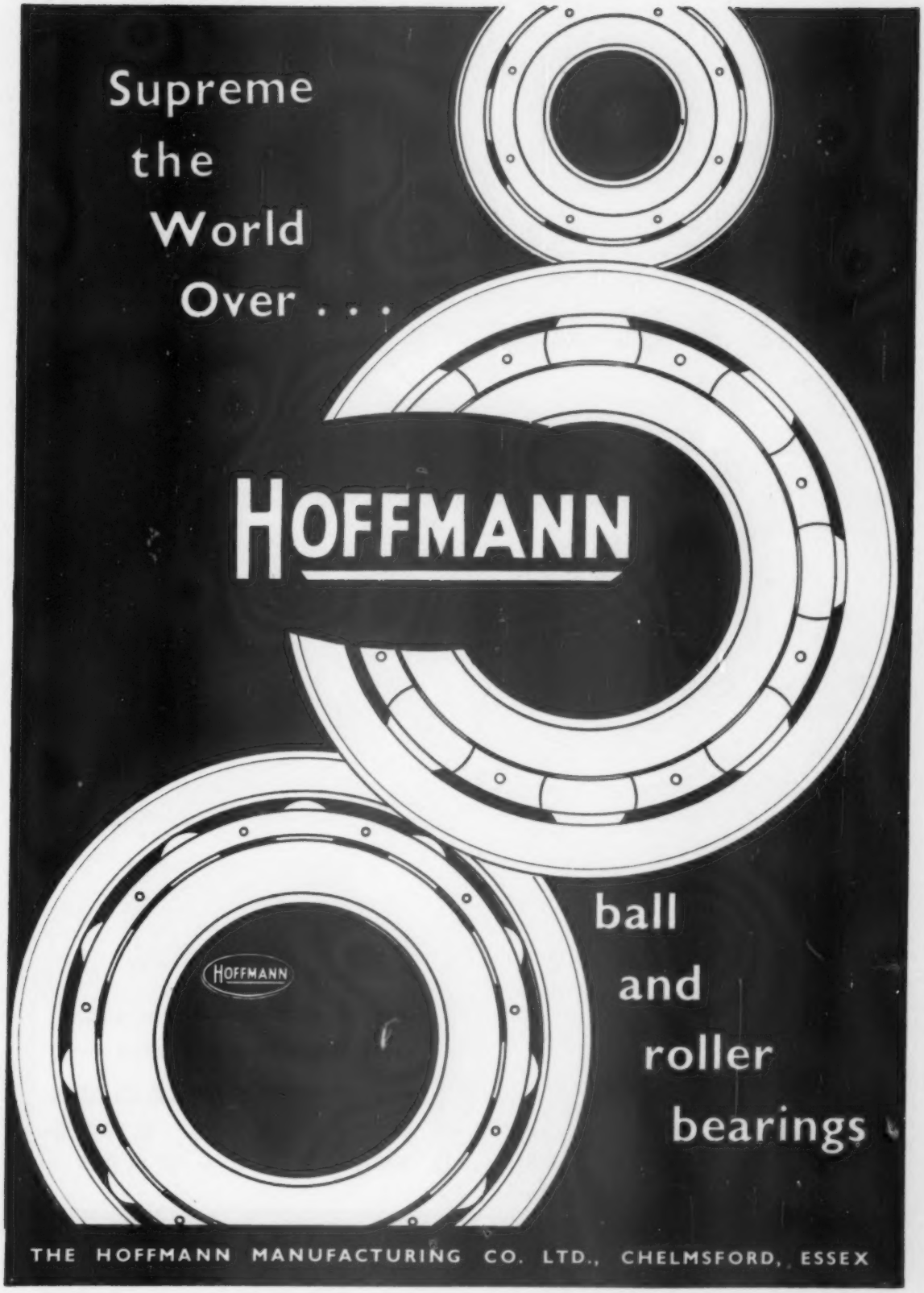
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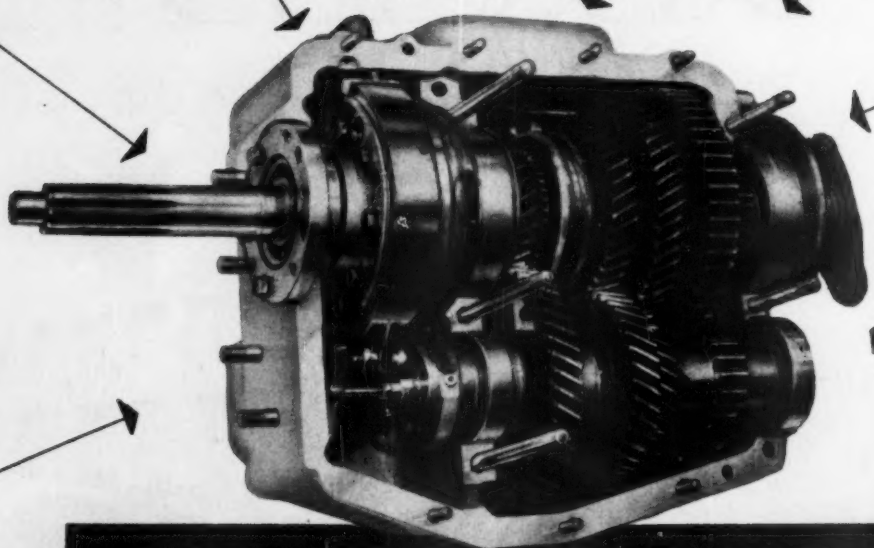

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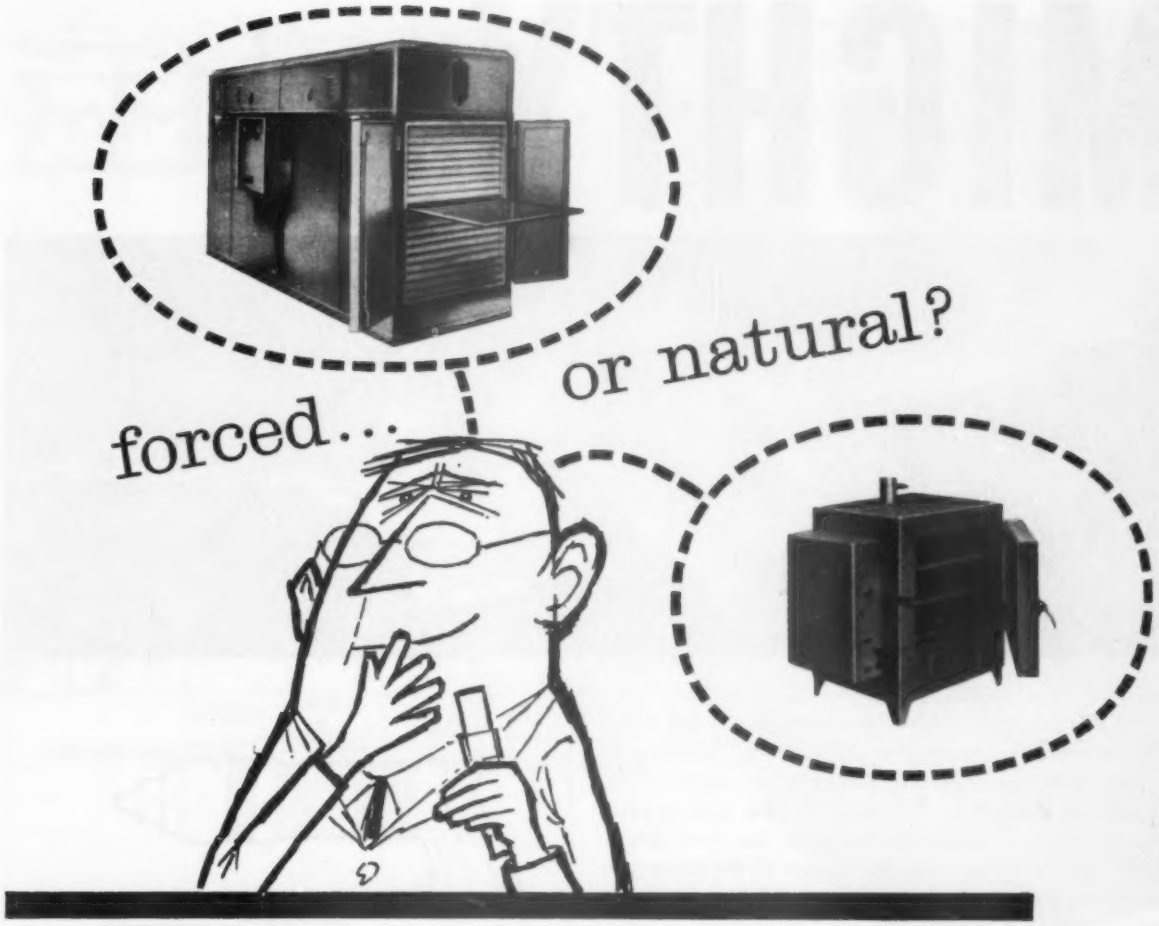

a forced convection oven (temperature up to 400°C)
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would "fill the bill", or maybe a 'special' is the answer.

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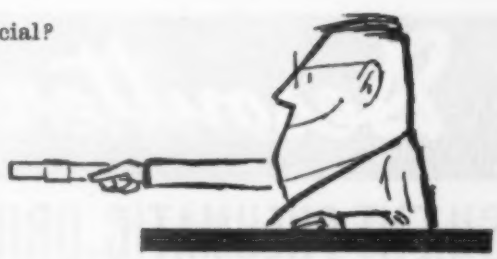
Large Oven? Small Oven? Automatic Oven?



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Desoutter Mighty Atom and Power Atom Pneumatic Drills

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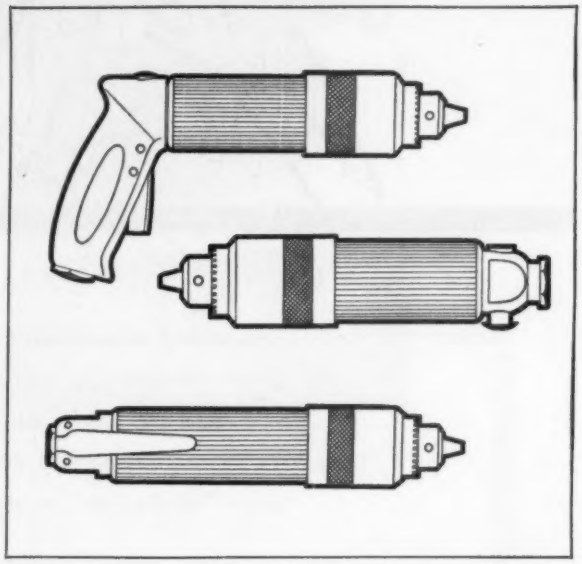
The new silent Mighty Atom and Power Atom drills cost no more than the earlier unsilenced models they replace. They're fitted with a push button control, as standard, but may be obtained with a pistol grip or lever control.



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SPECIFICATIONS

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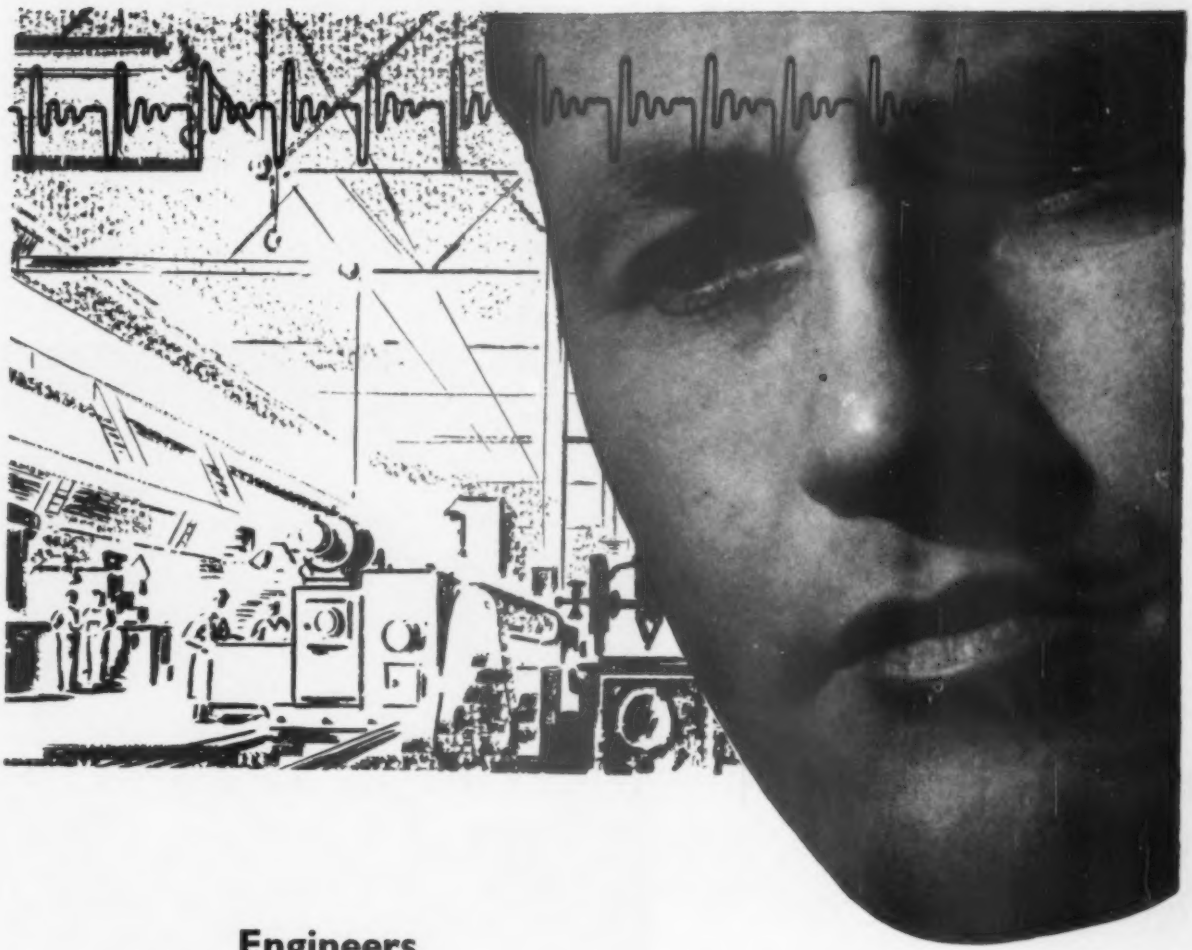
MA 13	$\frac{1}{4}$	6	1,000	$1\frac{1}{2}$	0·680	6-7	0·195
MA 22	$\frac{1}{4}$	6	310	$1\frac{1}{2}$	0·680	6-7	0·195
MA 29	$\frac{1}{4}$	6	550	$1\frac{1}{2}$	0·680	6-7	0·195
PA 1	$\frac{1}{4}$	6	2,500	$1\frac{1}{2}$	0·680	9-10	0·275
PA 2	$\frac{1}{4}$	6	4,500	$1\frac{1}{2}$	0·680	9-10	0·275

CRC 306



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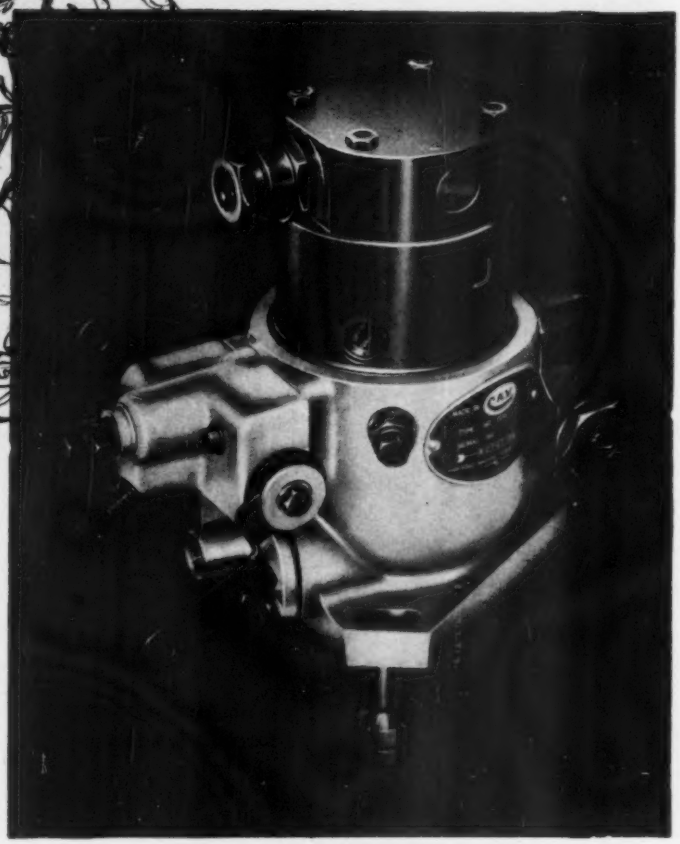

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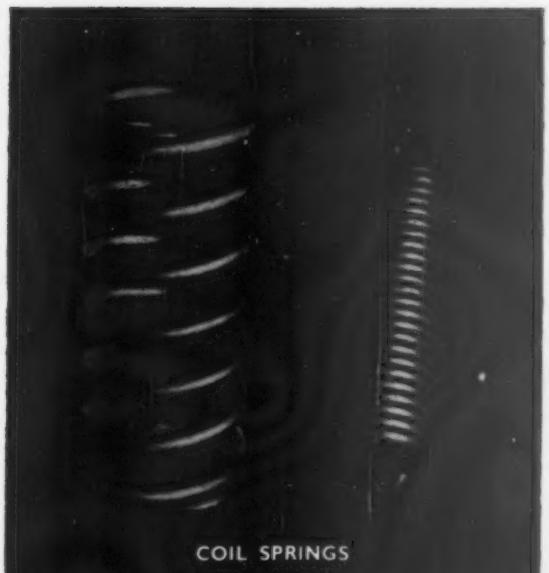

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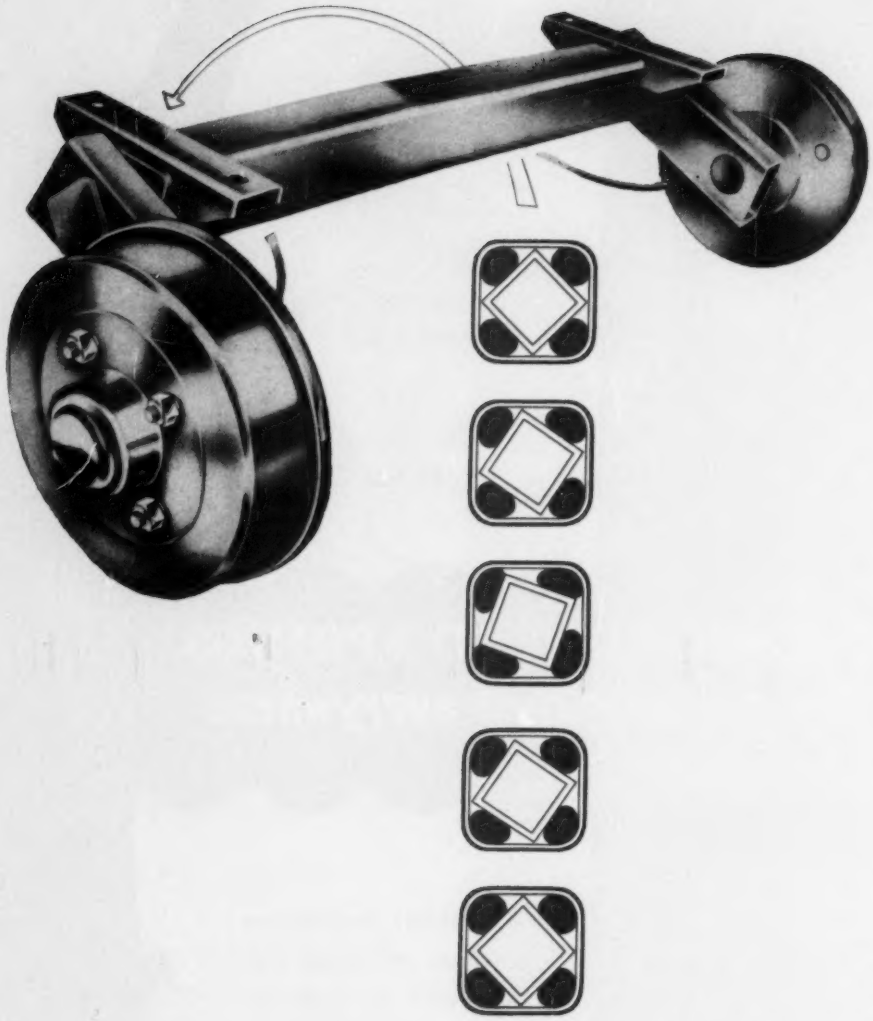

Ups and Downs

Here is a really different and better suspension system for trailers. The unique Andre-Neidhart spring units require no lubrication or maintenance; and the rubber springs, stressed in "rolling compression" will not deteriorate with regular use. They are ideal for their purpose and in most cases will outlast the vehicle.

Andre-Neidhart Trailer Suspensions by

ANDRE RUBBER

A SILENTBLOC COMPANY

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* versatile
* powerful

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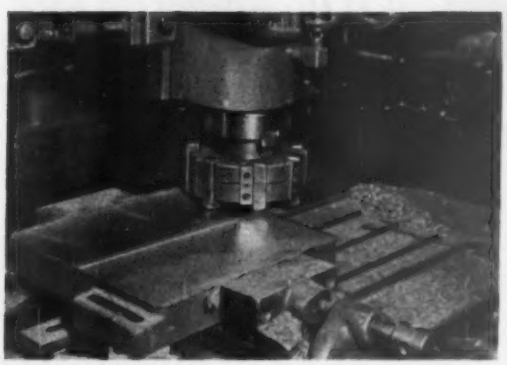

This massive, powerful and versatile machine makes light work of heavy duty milling on a variety of jobs at Forgrove Machinery Co. Ltd., Leeds.

Table has reversible automatic feeds and quick power traverse in all three directions. Speeds and feeds changed from front of machine. Direct reading dials. Twelve speeds from 29/520 r.p.m. or alternatively 36/638 r.p.m. Twelve feeds, ¼" to 20 in. per minute. Quick and fine hand adjustment to spindle. Table working surface 53" × 14½'.

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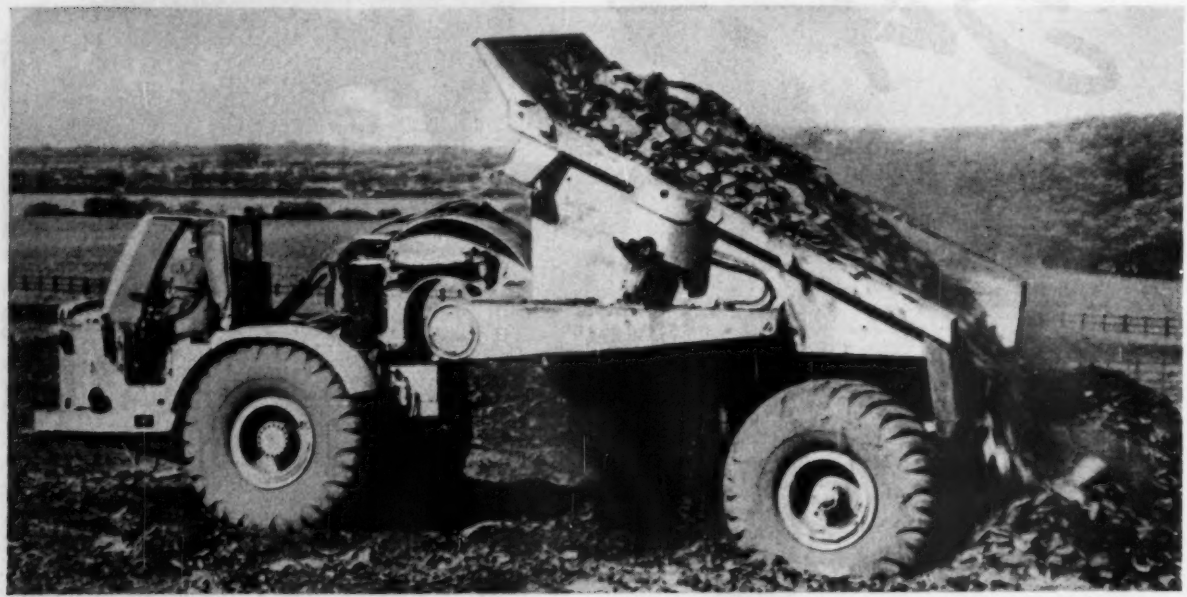
Today, four years later, the range of application for SCW Cor-Ten continues to grow as more designers and more users discover new ways in which they can take advantage of its outstanding properties.

Photograph by courtesy of Caterpillar Tractor Company Ltd.



Wherever higher strength or greater resistance to atmospheric corrosion offer economic advantages, SCW Cor-Ten *has been used. Where corrosion and abrasion are both present (as in the case above)* SCW Cor-Ten's *outstanding advantages are particularly effective.*

COR-TEN IS TOUGHER

- Weight for weight, the yield strength of SCW Cor-Ten is 50% higher than ordinary mild steel
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  Strength for strength, a saving of ⅓ of the weight is possible
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- Initial costs are spread over a longer service life
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- Operating costs are lowered—in transport applications payloads are bigger because of reduction in tare weight

Please write to us at the address below for further information or for technical assistance in the application of SCW Cor-Ten *to your products*

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for the HEAVY VEHICLE

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Accommodating pivotal movements such as those in suspension linkage and spring pivots, these bushes are relatively free torsionally, adding but little to the spring stiffness. They are very stiff axially and radially and support heavy loads.

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Permitting universal pivotal movements combined with large loads, Spherilastik bearings are being used with great success on a number of new suspension systems. Rubber is bonded to the spherical inner member and to the outer member which is in three segments. Force-fitting in the housing pre-loads the rubber to increase life and load capacity.

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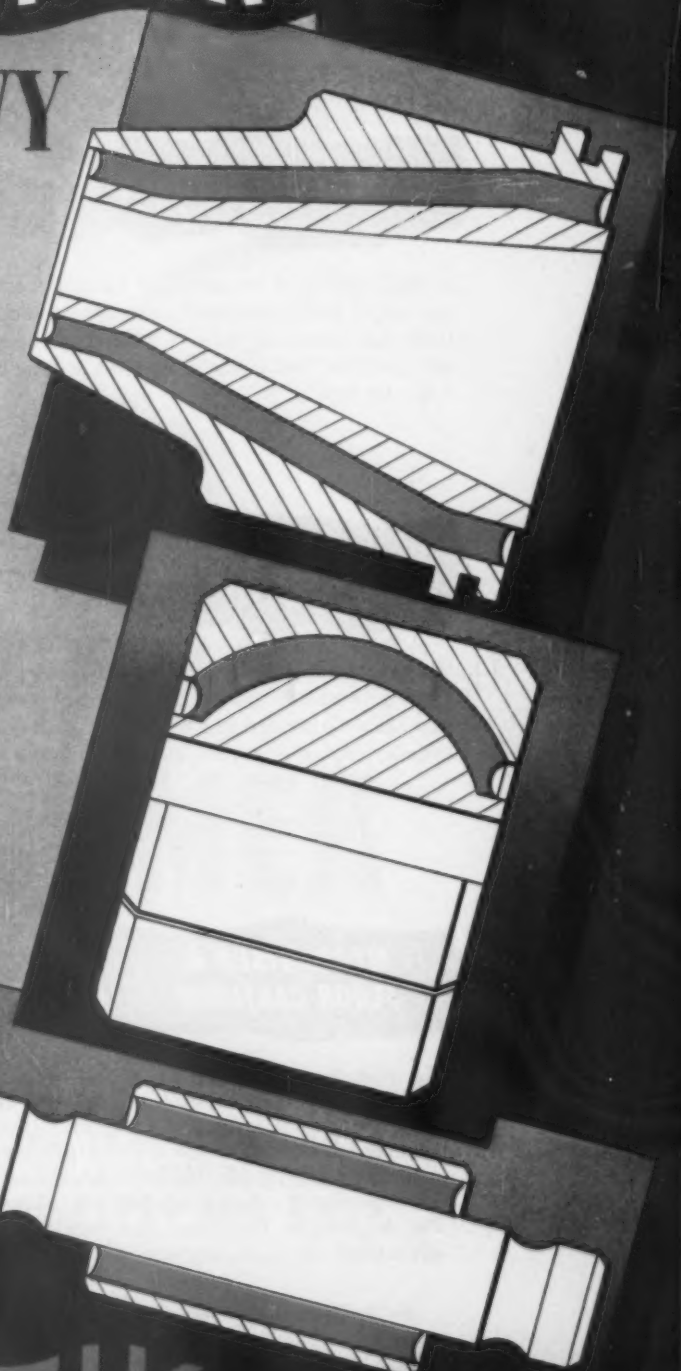
These are made in two types, one as illustrated and the other a still heavier duty type. They are giving amazingly long mileages in spring shackles on heavy vehicles.

Whatever your suspension, transmission or vibration problems may be, our engineers are always at your disposal.



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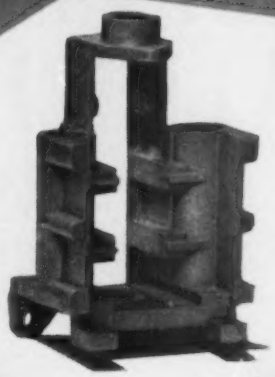
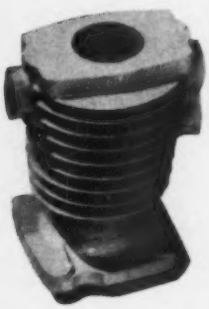
A large battery of Pressure Die Casting machines can supply quality castings for continuous supply in large quantities—on time. A wide range of alloys are available. This frame is supplied in Zinc-based Alloy BS.1004A.



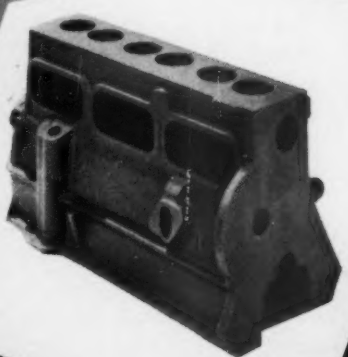
GRAVITY DIE CASTINGS

We have available a large Aluminium Gravity Die Casting Foundry where high quality precision castings are produced in a wide range of alloys. The cylinder shown is gravity die cast in LM.4 alloy.



MECHANISED & FLOOR CASTINGS

The Iron Foundries consist of five mechanised moulding units for castings up to 500 lbs. weight, maximum size 4 ft. x 3 ft. and a floor casting section handling up to 5 tons weight. Careful tests are made at all stages and castings can be balanced and locations machined to reduce machine shop time.
The Aluminium Foundries also include a large mechanised and a jobbing section.



We shall be pleased to help on your next casting problem.

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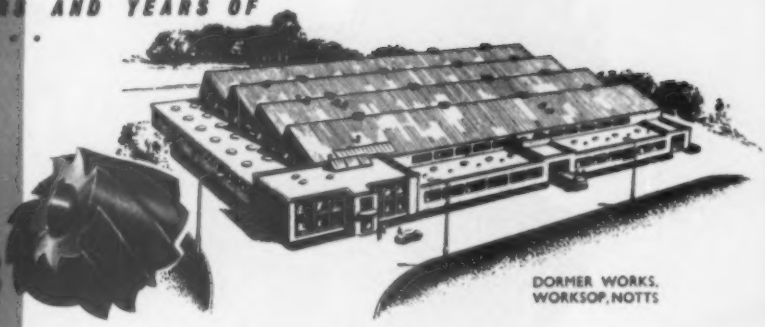

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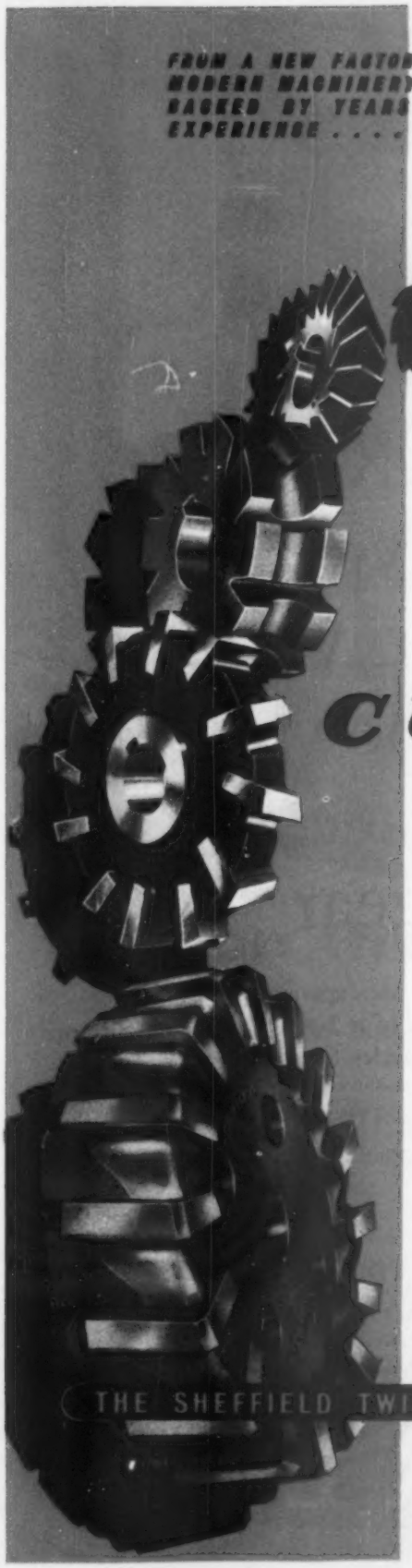

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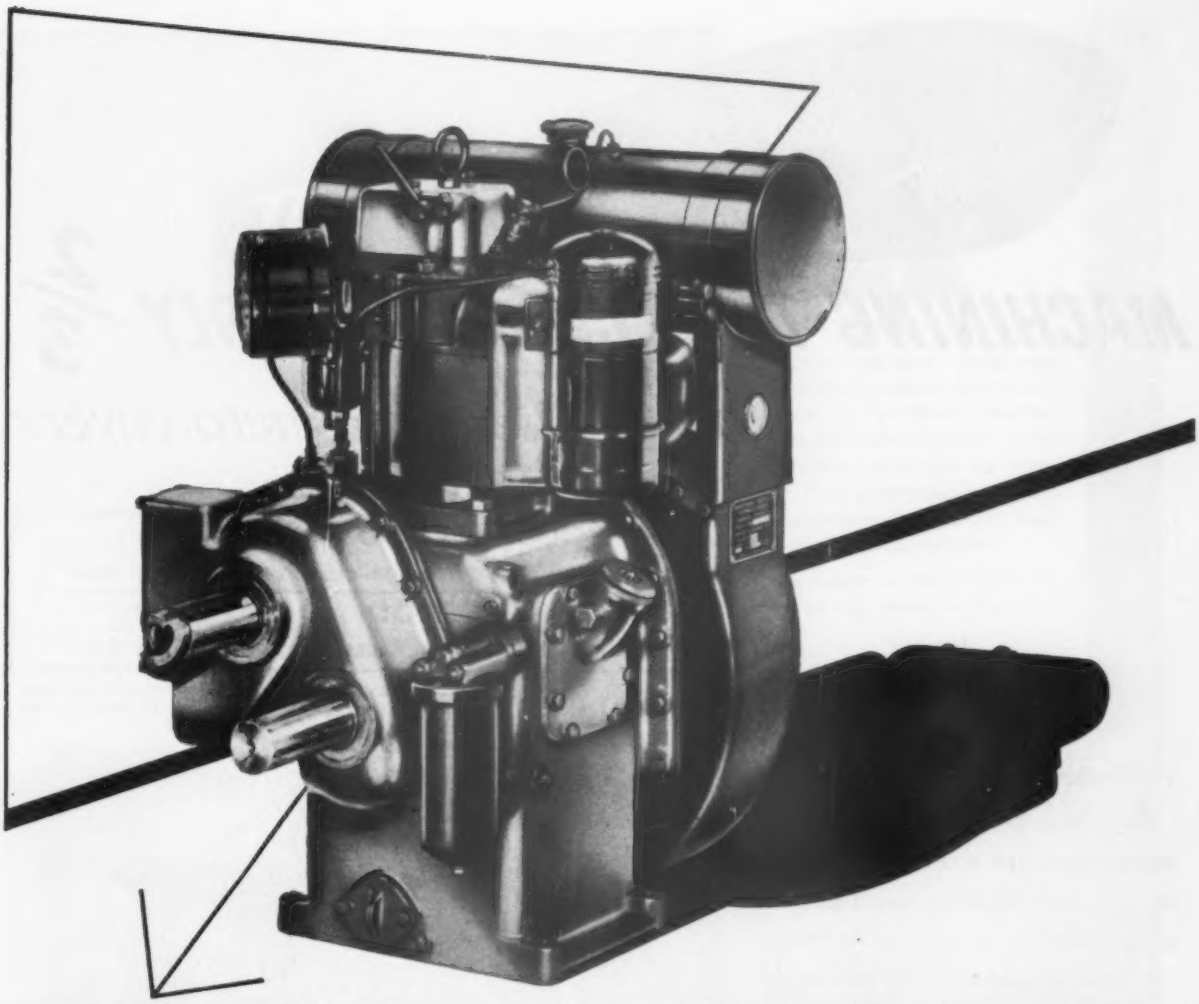
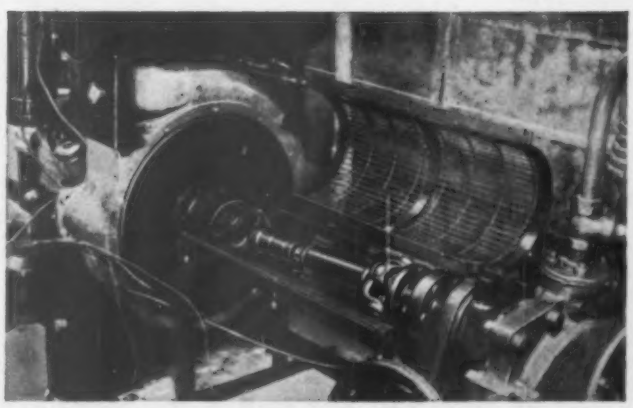


feet on the ground at Ansty

Armstrong Siddeley Motors Limited—famous for developing the Double Mamba and other aero engines, and rocket motors—keep their feet firmly on the ground, as well. Ansty is the birthplace not only of high-altitude engines, but also of diesels for industrial, agricultural, marine and land transport use. HARDY SPICER LTD. are proud that their cardan shafts and universal joints are relied on extensively on the development test stands at the Ansty Engineering and Research Centre of Armstrong Siddeley Motors Limited.



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PREVIOUS METHOD *Face milling on vertical miller*	**13** pieces per hour
PRESENT METHOD *Face milling on Wadkin Router*	**32·4*** pieces per hour

**When the operator becomes fully proficient in the operation of the Wadkin Router, the rate of production is expected to reach 37 pieces per hour.*

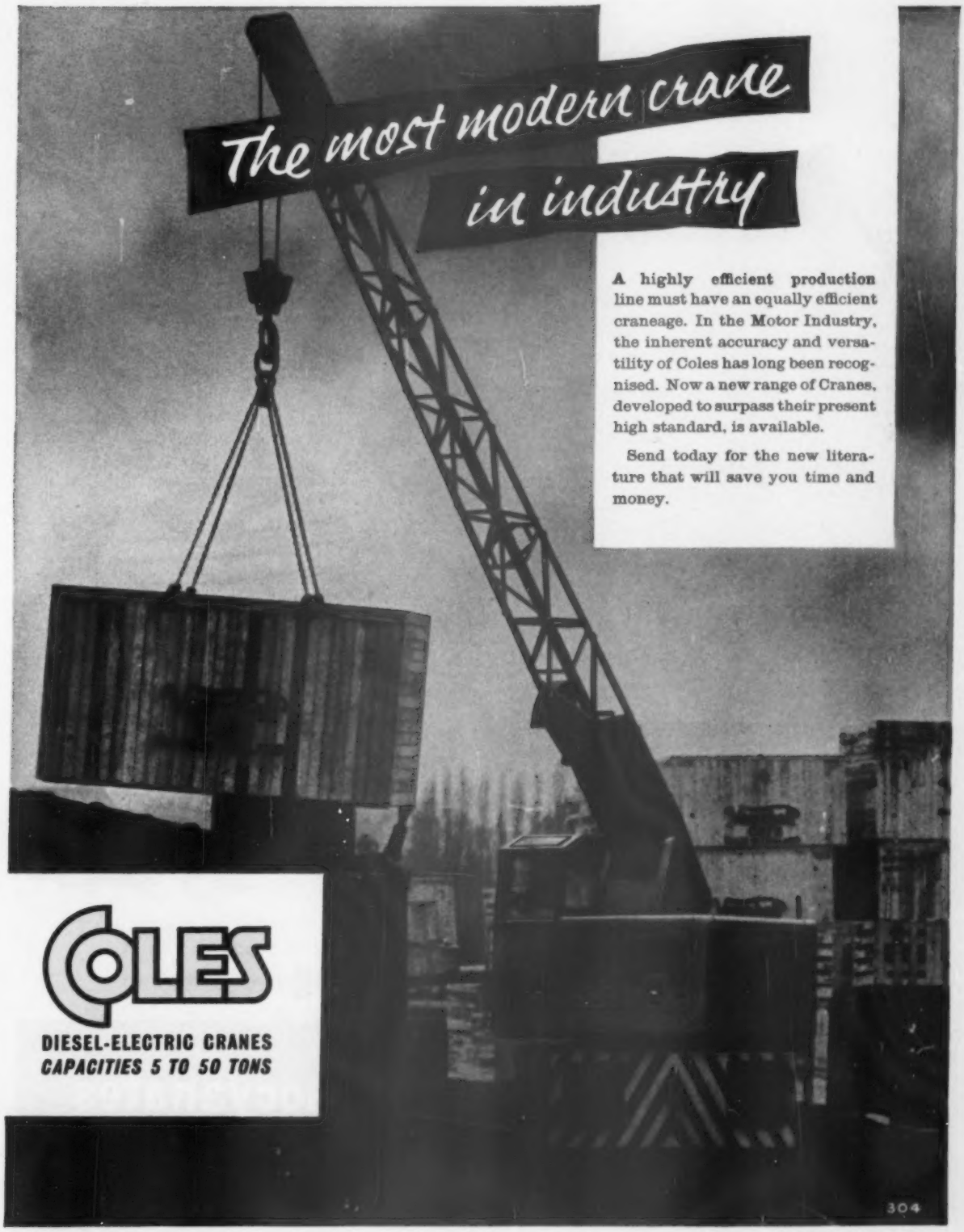
The Wadkin High Speed Router does the face-milling operation on this light alloy magneto cover with a saving of more than 60% of former machining time. This is not an unusual result—it's typical of the Wadkin Router's performance on Non-ferrous Metals. Unlike conventional machines the Wadkin L.S.M., shown on right, has cutting speeds up to 24,000 r.p.m. This guarantees a perfectly machined face requiring no further finishing operation, and only light clamping of the component is necessary. Write for a copy of Leaflet No. 603, which describes the machine and its applications.

Wadkin

Wadkin Ltd., Green Lane Works, Leicester

Telephones: Leicester 68151 (7 lines)

London Office: 62 Brook St., W.1. Tel. MAYfair 7048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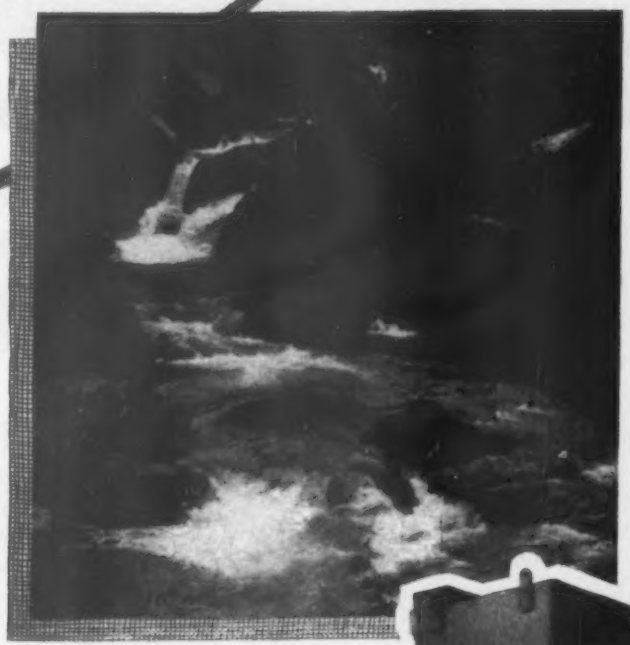

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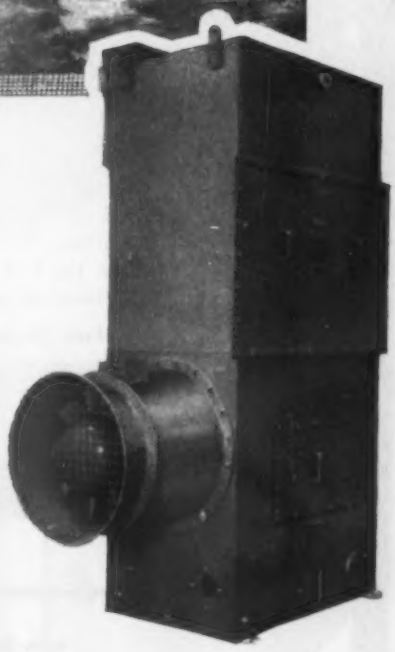

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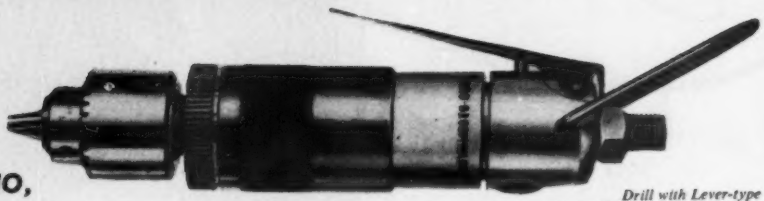

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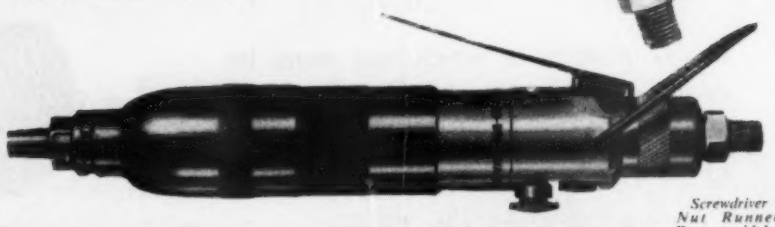

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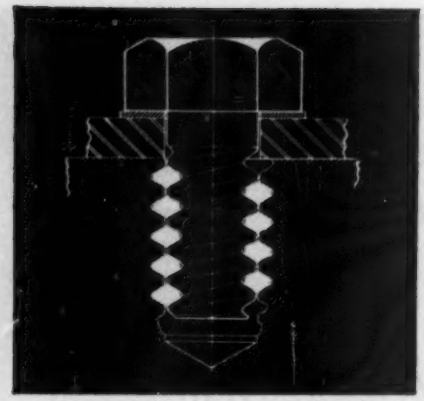

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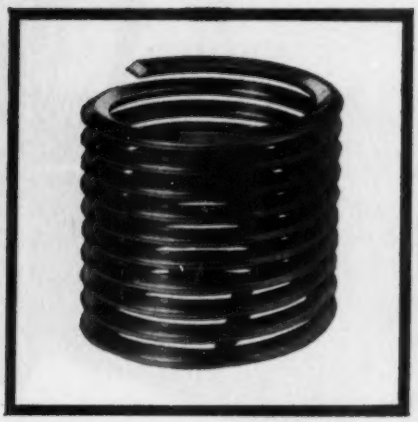

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Heli-Coil Inserts are self-anchoring thread liners made from high tensile stainless steel wire. In tapped holes they provide a conventional thread with higher loading strengths and greater resistance to wear and stresses than unprotected threads. The Heli-Coil eliminates stripping, seizing, galling and corrosion. It literally *armours* the thread. The Heli-Coil offers a unique opportunity for product cost revision. It is "a natural" for automation, it can make dramatic cuts in time and labour costs. Assembly is the ultimate in simplicity—just drill, tap and install. The Heli-Coil saves weight and space. It improves the serviceability and appearance of the end product. We suggest you write soon for data on Heli-Coil, the British-made Insert that is available internationally. It is a product of the day and this atomic age.

For further details write for sales leaflet APL. 48/E2.

ARMSTRONG PATENTS CO. LTD. EASTGATE, BEVERLEY, YORKSHIRE

BEVERLEY 82212

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* this makes sense
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'Eclipse' tool bits are made from H3 cobalt high speed steel, melted, heat treated and finished under one control to strict and rigid standards of quality. That's why the consistent performance of 'Eclipse' tool bits can be guaranteed.

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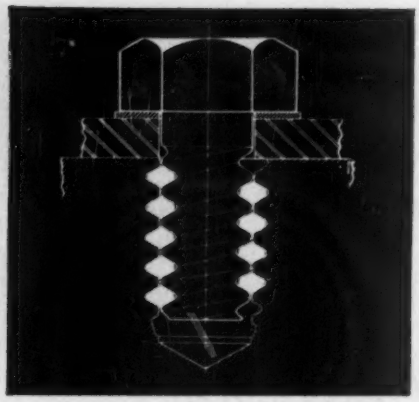
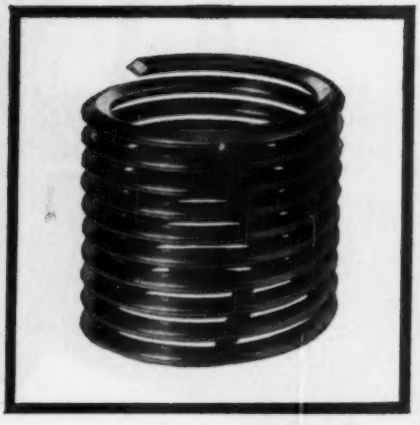
'Eclipse' hacksaw blades and other tools are made by James Neill & Co. (Sheffield) Ltd. and are obtainable from all tool distributors.

UT 13

Ask the machine shop to check this



almost limitless possibilities of saving in time and cost



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screw thread inserts

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- Excellent copies obtainable from old or faded originals.
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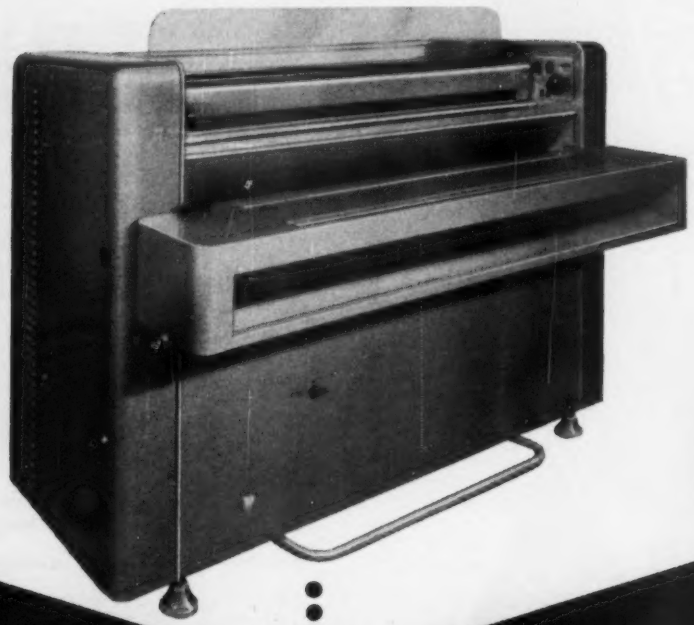

and no unpleasant fumes

Capacity: rolls and cut sheets up to 42 in. wide. Printing speed: 6 in. to 15½ ft. per minute. Lamp: H.P.M.V. MA/U 2,000 watt. Dimensions: height 50in., width 67in., depth (tray extended) 52in. Weight: 850 lb.

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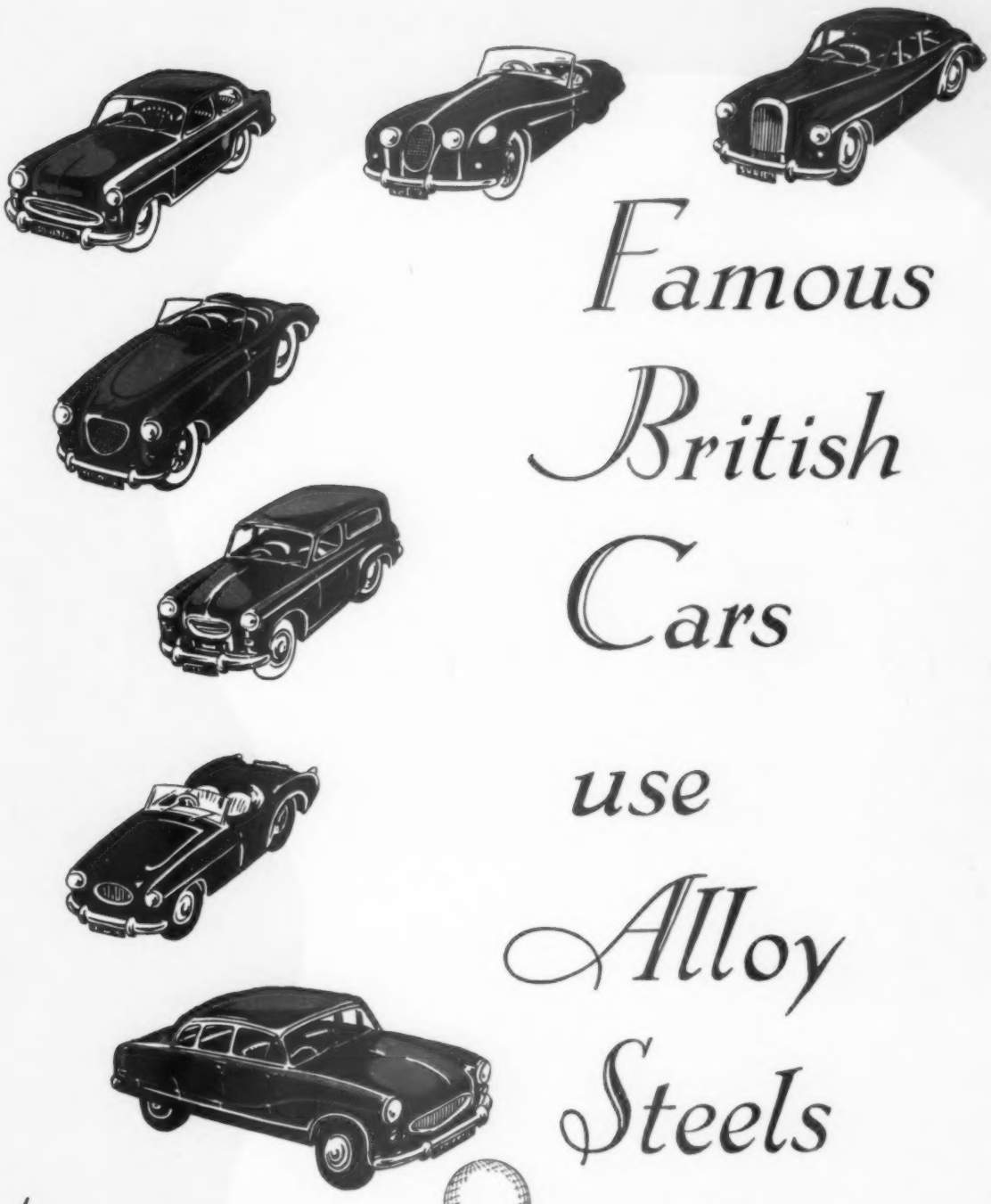
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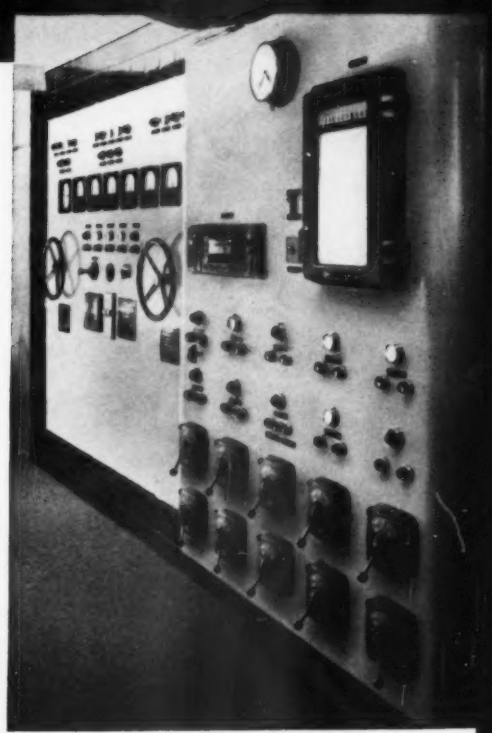

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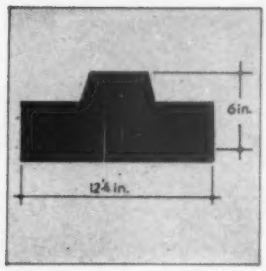

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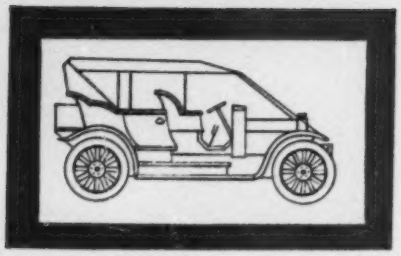

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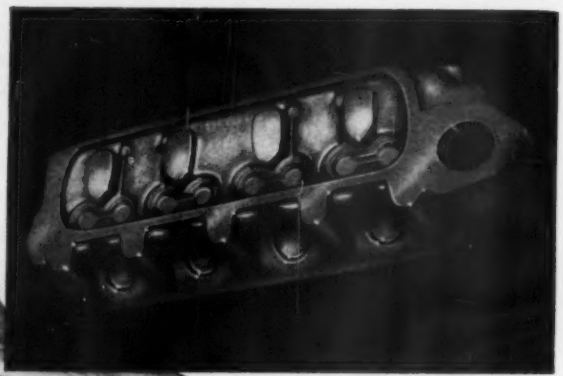

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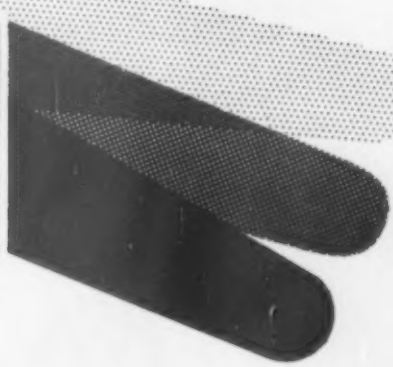

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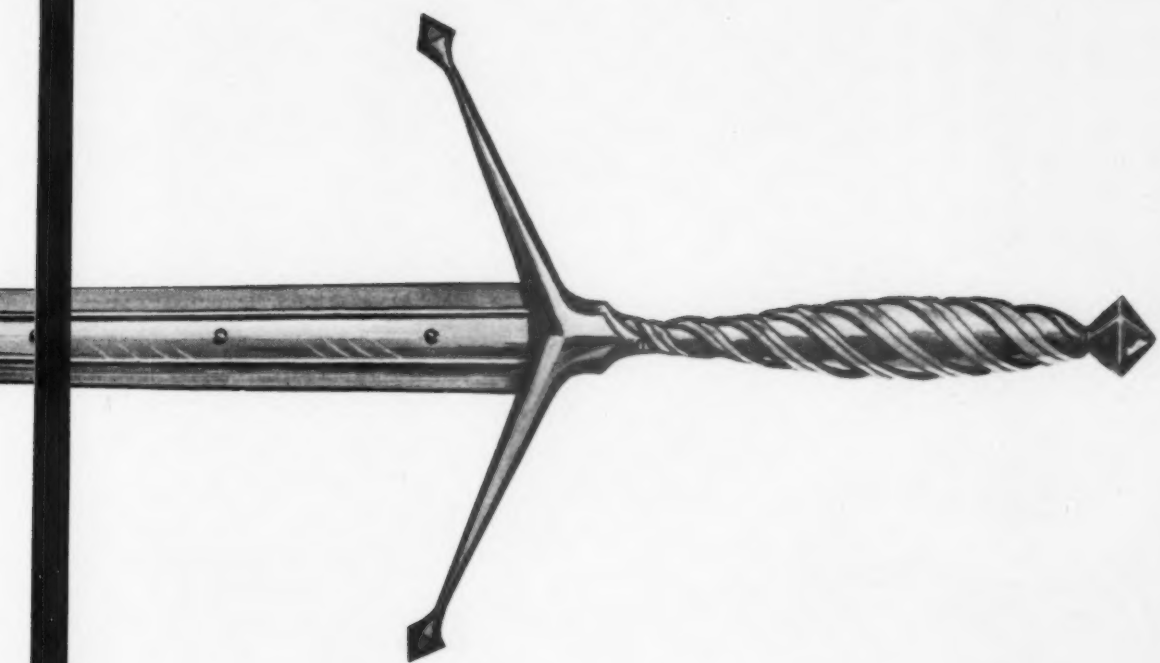

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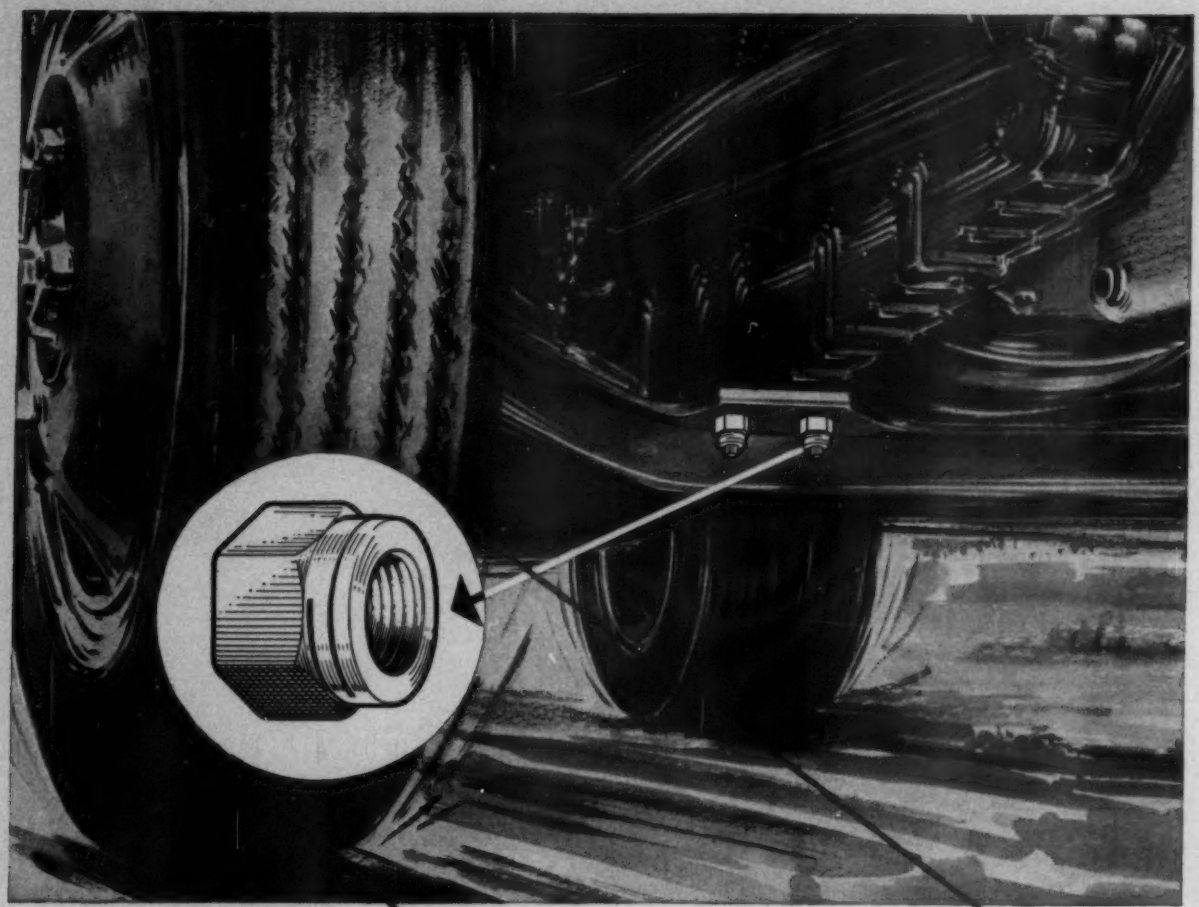

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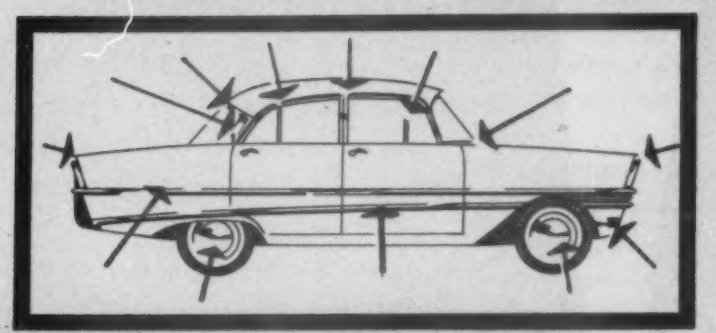

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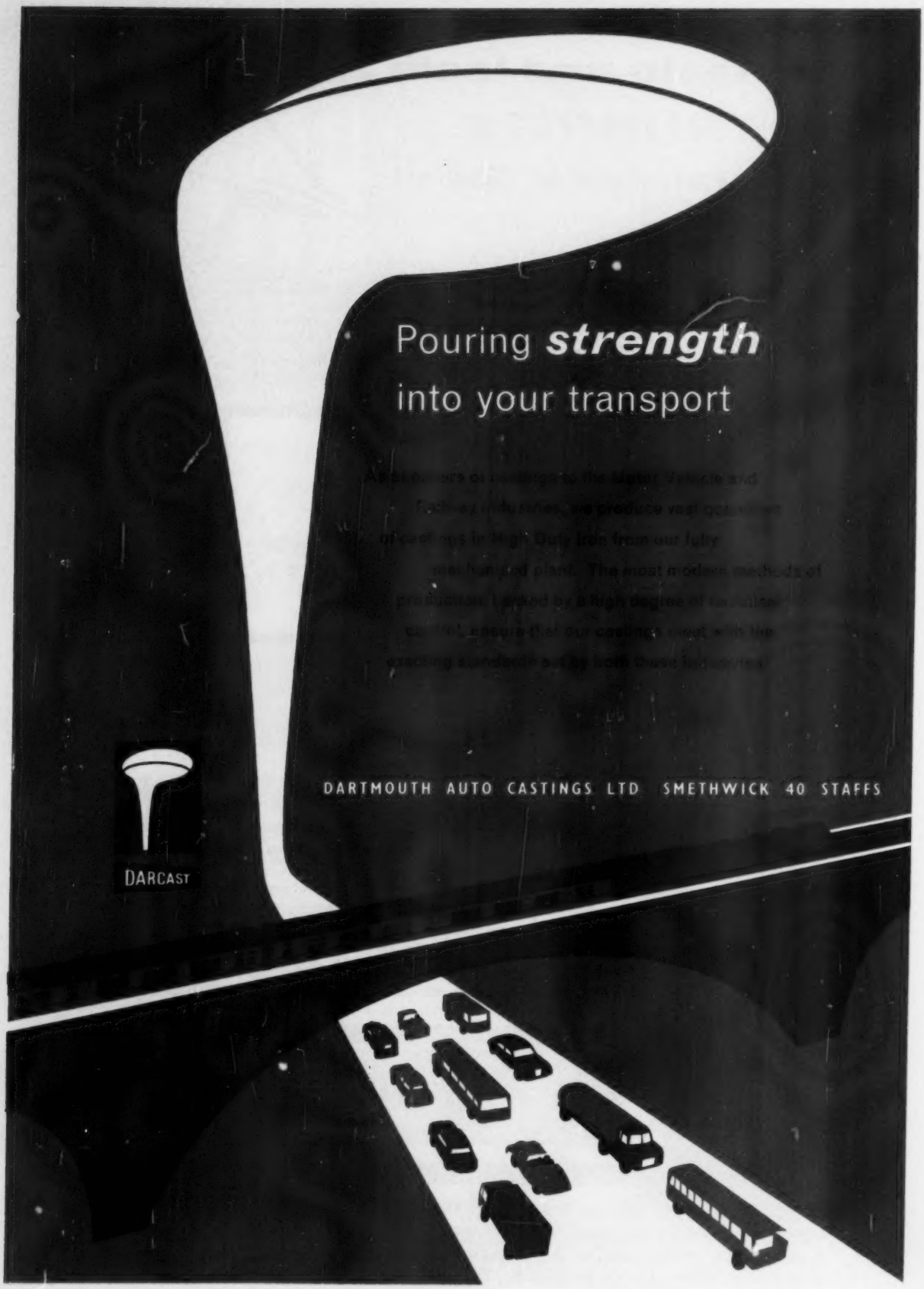
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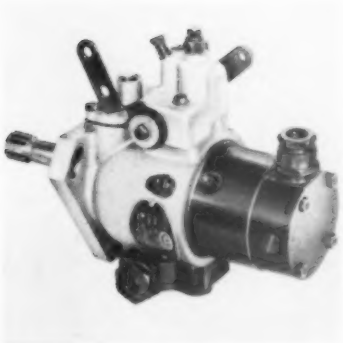

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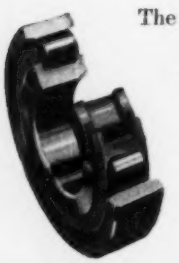

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DESIGN MATERIALS **AUTOMOBILE ENGINEER** PRODUCTION METHODS WORKS EQUIPMENT

The Overhead Camshaft

TOWARDS the end of last November a discussion on the subject of accessibility, in relation to the modern car, was held in London by the Automobile Division of the Institution of Mechanical Engineers. A number of speakers stressed the desirability of judging accessibility, not by some ideal standard but in terms of the necessary frequency of attention. It was maintained that, on this latter basis, certain current engine designs, incorporating push rod actuated valves, could be criticized on the ground that valve clearance adjustment is needed too frequently.

The reason for the undesirably rapid wear on push rod and rocker mechanisms is usually the large number of bearing surfaces between the camshaft and the valve stems. Although a system may be irreproachable so far as its effective life is concerned, the sum of the individually negligible wear rates can be appreciable and call for frequent adjustment. Also, where the camshaft is in the crankcase, the flexibility of the long push rods can give rise to vibration that leads to a relatively high rate of wear and reduces mechanical efficiency.

During the discussion at the Institution, the principal speaker advocated the single overhead camshaft as a better compromise than a side mounted camshaft, push rods and rockers. Higher operational efficiency is an obvious advantage of the overhead camshaft, but there seems to be a general failure to appreciate how well this layout is suited for use with at least two of the currently popular combustion chamber arrangements. In the majority of bath-tub and wedge-type chambers, the valve stems are parallel, either vertical or inclined, and all in the same plane. With such a disposition, the valves can be actuated directly by a single overhead camshaft and piston-type tappets—a robust and simple mechanism.

The piston-type tappet arrangement scores additionally over rocker actuation in that it does not impart any side thrust to the valve, so the life of the guides and seats is improved. Since the tappets are generally large enough to embrace the springs, they automatically have sufficient peripheral bearing area to resist the lateral loading applied by the cams. It has been argued that there is considerable friction on this large surface area. However, the popularity of the layout for high-efficiency engines suggests that this bogy is not a serious one. With direct valve operation of the type under discussion, the weight, and hence the inertia, of the reciprocating parts is lower than with a comparable push rod mechanism. As a result, the rate of the valve springs can be lower, so loadings are reduced and operation should be quieter over the whole range.

Those who view this overhead camshaft layout with disfavour point out that valve clearance adjustment has to be done either by grinding the ends of the valve stems or by fitting shims between them and the tappets. Such adjustment is thus hardly a task for the average owner. Up to a point, this is a valid criticism, but it brings us back to the original issue: if the period between these adjustments is sufficiently long, the more difficult adjustment is acceptable even though access may be awkward. It could reasonably be expected that a properly designed overhead camshaft system should only require adjustment of valve clearances when the head has to be removed for decarbonizing and attention to the valve seating faces. In any case, there need be no special difficulty in arranging for the removal of the camshaft without disturbing the timing.

The greater cost of the overhead camshaft mechanism relative to that of the push rod type is frequently cited as the most important single reason against its adoption for low-price, quantity produced cars. To what extent do the facts justify condemnation in the case under consideration? The drive to the camshaft has to be lengthened, either by the employment of a longer chain, or by the use of a two-stage arrangement. Certainly the adoption of a two-stage drive involves added cost, but the possibility of using a longer chain should be considered in the light of the fact that tensioners have been much improved during the last few years, although some may also be more expensive than the earlier ones.

On the credit side, the boring of tappet guides in the block is eliminated, as are the push rods, the overhead rockers and their shaft. There is no reason why piston-type tappets should be appreciably more expensive to produce than those for use with push rods, and it should be possible to run them directly in the cylinder head. The lubrication system would be simplified, while the umbrella effect of the tappets should prevent excessive oil loss down the valve guides. Any added complexity of the head casting is countered by the corresponding simplification of the block.

Where the valves are parallel and in line, there would seem to be a good case for the single overhead camshaft on petrol and certain diesel engines. For V-eight and V-twelve units, however, the balance is probably still in favour of the push rod design: the single camshaft, mounted relatively high in the crankcase, and the short push rods provide a simpler and stiffer valve actuation gear than that of an in-line engine of conventional arrangement.

The C.A.V. DPA Fuel Pump

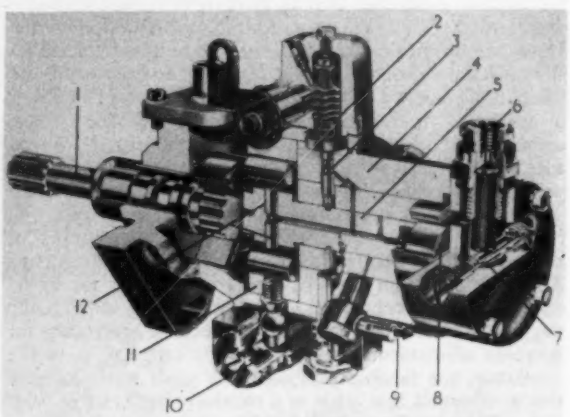
Development and Construction of an Efficient, Compact and Low-Priced Distributor Type Fuel Injection Pump

IN November 1956, C.A.V. Ltd. introduced their DPA distributor type fuel injection pump, and thereby made a marked contribution to the development of the small, high-speed compression-ignition engine. Since that date over 150,000 pumps of this type have gone into service on a variety of applications, including private cars, taxis, cross-country and commercial vehicles, as well as tractors and generating sets. The number of engines already fitted with the DPA pump as standard equipment now totals nine, from four manufacturers, and several additions should be released in the near future.

Before turning to a description of the construction and operation of the pump, it is interesting to consider what led up to its introduction. Early in the post-war period, pressure from engine manufacturers made it clear to C.A.V. that if the diesel engine was to fulfil its potential in the smaller sizes, the cost of fuel injection equipment would have to be reduced. Although much work had been done in this direction on the in-line type of pump, there was an obvious limit to what could be achieved. The smaller the engine, the greater becomes the proportional cost of the fuel injection unit, and it was apparent to the C.A.V. engineers that a radical simplification of pump design was necessary to obtain the desired results. For this main reason the distributor type of injection pump looked promising. A further important advantage, however, was its inherent ability to run at higher speeds than the in-line pump; also, because of its basic simplicity, it should be operationally reliable and cheap to maintain.

As is well known, the principle of this type of fuel pump is the use of a single pumping element to feed the fuel to a rotary distributor supplying the individual injectors in the correct order. Having decided to investigate the distributor pump, C.A.V. developed several such designs. The pumps evolved were compact and possessed useful characteristics but their relatively complex distributor mechanism called for a very high standard of accuracy in manufacture. Not the least of the difficulties was one which is fundamental with small diesel engines: the small quantity of fuel per delivery of the pump, and hence the necessity of minimal calibration variations as between one cylinder and another.

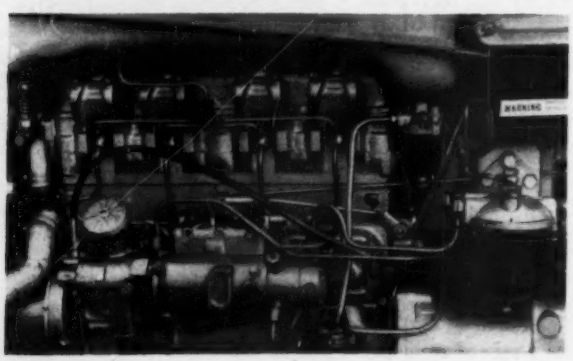
In spite of the intensive work carried out over several years, the results obtained by 1953 were not as favourable as had been hoped. After close review of the work done elsewhere, as well as at C.A.V., interest was directed towards the distributor type pump then under development by the Hartford Machine Screw Co. in the United States of America. This pump, which operated on different principles from those investigated by C.A.V., lent itself to low-cost manufacture by virtue of its design simplicity, and was capable of running at satisfactorily high speeds. Moreover, it readily permitted the incorporation of those automatic variations of the injection timing which had been found necessary for successful engine operation over wide speed ranges. Installation was easy and a relatively low-power drive was required. Although not in normal production, the Hartford pump had already been under development for a number of years and had proved successful on a large variety of engines.



1 *splined drive shaft;* **2** *hydraulic governor;* **3** *metering valve;* **4** *hydraulic head;* **5** *pumping and distributing rotor;* **6** *fuel inlet;* **7** *regulating valve;* **8** *transfer pump;* **9** *fuel outlet;* **10** *automatic advance device;* **11** *cam ring;* **12** *pumping plungers*

The constructional simplicity and compactness of the DPA pump is shown by this sectioned view of the hydraulically governed version

On the Ferguson agricultural tractor, the DPA pump is horizontal and is fitted with a mechanical governor giving very precise control



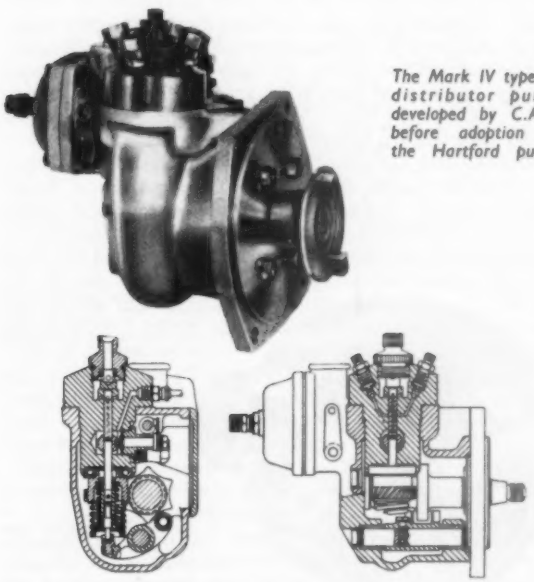
An agreement for the further development and production of this design was therefore concluded by C.A.V., and the development programme was at once put in hand at Acton. This was particularly concerned with the adaptation of the pump to suit British and European engines. Laboratory testing was followed by lengthy experience on the engine test beds and finally under actual service conditions. Over 100 pumps were employed for the service trials and were run for more than 150,000 hours in all weathers and on numerous different applications. So satisfactory were the results of these tests that large-scale production was put in hand at the

C.A.V. factory at Rochester. This new venture necessitated the installation of many new special-purpose machine tools and the organization of a considerable degree of automatic operation and checking to attain the desired standards.

Description and Operation

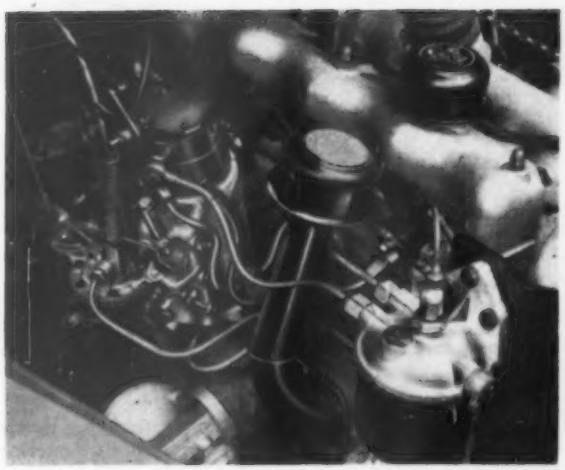
The DPA pump is of the opposed plunger pattern. An interesting feature is the absence of gears and ball or roller bearings. The number of working parts is, of course, independent of the number of engine cylinders. Since the pump and its governor form an oil-tight unit in which pressure is maintained, the entry of dust and water is prevented; also, the moving parts are lubricated by filtered fuel oil, so that no additional oil supply is required.

Two important features of a fuel pump are accurate calibration as between one cylinder and another, and correct phasing, that is, ensuring that the injection timing is the same for each cylinder. In the DPA pump they are inherent in the design, depending only on accuracy of manufacture and not on external setting or adjustment. Since the reciprocating masses are small and the plungers are returned hydraulically, instead of by springs, the pump can operate efficiently at high speeds. At the present stage of development the limit is in the region of 12,000 deliveries per minute, but it is expected that further improvements will be possible. C.A.V. prefer to quote deliveries per minute rather than pump or engine revolutions per minute, because the limiting factor is the ability to recharge the pump between successive injections. Two types of governor are available, one mechanical and the other hydraulic. For this distributor form of pump, the hydraulic governor is simpler and cheaper than the mechanical type; it also results in a more compact pump assembly, and so gives an advantage where installation space is at a premium. The mechanical governor, on the other hand, permits very precise control of speed.



The Mark IV type of distributor pump developed by C.A.V. before adoption of the Hartford pump

On the splined driving shaft of the pump, and rotating with it, are two assemblies. Of these, the one more remote from the driving end of the shaft is the fuel transfer pump, and that adjacent to it is the pumping and distributing rotor. The transfer pump is of the continuous discharge, sliding vane type. It raises the pressure of the fuel to an intermediate level and delivers it through internal passages to the governor-controlled metering valve. The delivery pressure of the transfer pump is controlled by a by-pass valve which will be referred to again later. To avoid any possibility of incorrect timing on initial fitting or subsequent refitting of a pump, there is a master spline in the drive to the pump shaft.



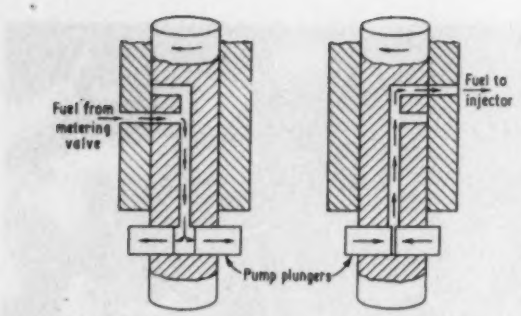
On the Land-Rover the nearly vertical pump is camshaft driven

The pumping section of the rotor is of a larger diameter than the distributing section, which is a close running fit in the hydraulic head. In the pumping portion is a cross-bore, in which slide the pumping plungers. By the use of two opposed plungers, side-thrust reaction on the rotor is obviated. The plungers are moved inward by means of a stationary cam ring, in the body of the pump, and roller followers carried in shoes free to slide radially in slots in the rotor. An aluminium alloy casing is employed, and the rotor, head and plungers are of hardened steel. Normally, there are as many lobes on the cam ring as there are cylinders in the engine, and they are equally spaced round the circumference of the ring.

An axial passage in the rotor connects the pumping space between the plungers with the fuel inlet and delivery ports. The radial inlet ports are disposed at equal intervals round the rotor and, as this revolves, align successively with a port in the hydraulic head. This latter port is supplied with fuel from the metering valve already mentioned. There is a single distributing port in the rotor, and this aligns in turn with the outlet ports in the hydraulic head. The outlet ports, too, are equally disposed round the circumference and are equal in number to the engine cylinders. They are connected to conventional injector nozzles in the cylinder head.

When one of the inlet ports in the rotor aligns with the port from the metering valve, the rollers are, of course, between successive lobes on the cam ring. Fuel, under transfer pump pressure, enters the axial passage in the rotor, the pressure causing the plungers to separate. As the rotor revolves, the inlet port is cut off, and further travel brings the distributor port in line with the appropriate outlet port in the head. Simultaneously, the rollers come into contact with the cams and the plungers are moved inward. Fuel is thus forced through the outlet port to the injector. After delivery is completed, the outlet port is cut off, one of the inlet ports aligns with the metering valve port and the cycle begins again.

Greater cam lift is actually available than is required for maximum fuel delivery; as a result, the rollers do not follow the base circle of the cam ring but come into contact with the lobes part way up their slope. The distance by which the



Diagrammatic representation of the DPA principle of operation: on the left is shown the charging stroke and on the right the injection stroke

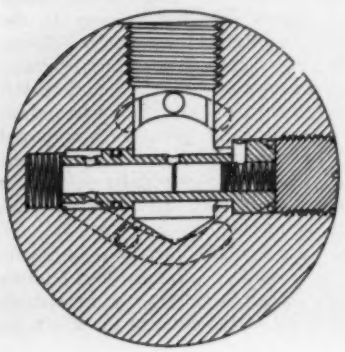
plungers separate—and so their stroke after the rollers contact the cams—depends on the amount of fuel entering the rotor; this quantity is controlled by the metering valve. It will be appreciated that no non-return valves are required in the system because, when any inlet port is in action, the distributor port is cut off, and conversely. To avoid dribbling of the injector nozzles, the cam profile is such as to provide a retraction period after full lift, and this results in the unloading of the fuel lines. Because the plungers are not spring loaded and the transfer pump resistance is continuous, the driving torque of the complete unit is always positive.

The only basic adjustment on the DPA pump is that to control the maximum amount of fuel admitted. This adjustment is effected in a very simple manner by varying the limit of outward travel of the roller shoes, and hence of the plungers. Retaining the roller shoes axially in their slots in the rotor are the upper and lower adjusting plates. To keep the plates mutually aligned, the lower of them has two bent-over tongues that engage in slots in the upper plate.

In each plate are two diametrically opposed slots, the outer edges of which have a curvature of cam form. Projecting into the slots from the ends of each shoe are lugs having a corresponding curvature on their outer faces. Outward movement of the shoes is limited by contact between the lugs and the slots. Two screws clamp the lower plate to the rotor; they pass through slots in the plate, which allow limited angular movement between the two assemblies. Such movement causes the lugs on the roller shoes to ride up or down the cam edges of the slots, thus altering the maximum outward travel permitted to the shoes.

The type of metering valve employed in the DPA pump depends on the governor fitted. With the hydraulic governor a piston valve is utilized, whereas the mechanically governed pump has a valve of rotary pattern. The pressure regulating valve is of the piston type and is operated by any differential that there may be between the pressure of the regulating spring and that of the transfer pump delivery, as modified by the setting of the metering valve at any particular instant. If the metering valve is closed, the full transfer pump pressure is applied to the piston of the valve; in consequence, the regulating spring is compressed and the by-pass valve fully opened to allow the fuel to flow back to the suction side of the transfer pump. As the metering valve opens, the hydraulic pressure is reduced on the piston, which therefore moves to reduce the amount of fuel by-passed.

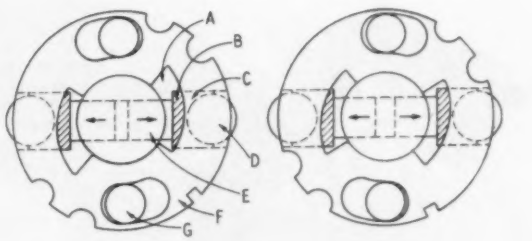
This valve additionally provides a means of by-passing the transfer pump during hand priming when the engine is stationary, and so enables the metering port in the hydraulic head to be filled before turning the engine. In this operation, the priming pressure—applied through the by-pass passage of the valve—causes the piston to move away from the regulating spring and to compress a secondary one, termed the priming spring, thereby uncovering a port leading to the delivery side of the pump, and so to the metering valve.



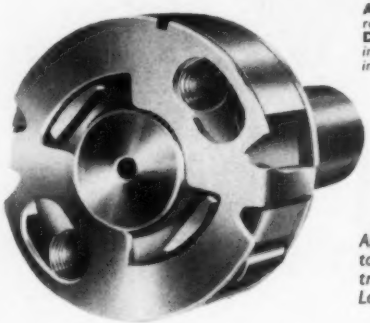
Section through the pressure regulating valve in the end plate. The priming spring can be seen on the left side

Governing

Before dealing in detail with the two types of governor, it should be mentioned that the governor has an easier duty on the DPA pump than on a conventional in-line pump. This is because of the inherently stable delivery characteristics of the pump. With helix-controlled pumps there is normally a tendency for the fuel delivery rate to increase with engine speed, for any particular setting of the control rod, particularly at light load. With the distributor pump, on the other hand, a minor increase in speed results in a reduction in the quantity of fuel delivered per cycle, because of the reduction in available filling time. A further advantage from the governing aspect is that the effort required to move the control valve is very small.



A *cam-shape slot;* **B** *lug on roller shoe;* **C** *roller shoe;* **D** *roller;* **E** *plunger;* **F** *adjusting plate;* **G** *locking screw hole in shoe carrier*



Above: The method used to adjust the maximum travel of the plungers. Left: The adjusting unit assembled for fitting

Both governors are of the all-speed type, and the simple hydraulic unit, housed in a small casting attached to the side of the pump body, gives control comparable with that of a pneumatic governor on an in-line pump. With this type of governor, the metering valve piston is a sliding fit in a cross-bore in the hydraulic head and has an annular groove fed by fuel, at transfer pressure, through internal drillways from its inner end. As can be seen from the

accompanying illustration, the passage of fuel to the metering port is controlled by the axial position of the groove in relation to the port.

On the valve stem are the main governor spring and the light idling spring; they are separated by a cylindrical rack member which is engaged by pinion teeth cut on the control lever shaft. A large disc on the valve acts as a damper to reduce sudden movements. The position of the metering valve during normal running is controlled by the main spring pressure in opposition to the transfer pump pressure: an increase in engine speed raises the transfer pressure and so reduces the valve opening until equilibrium is reached. When the control is moved towards the idling stop, the main spring pressure is reduced and the idling spring is eventually brought into action. Operation of the over-riding shut-off lever causes a cam, on the lever spindle, to bear on the washer that retains the idling spring and lift the metering valve, thus cutting off the fuel completely.

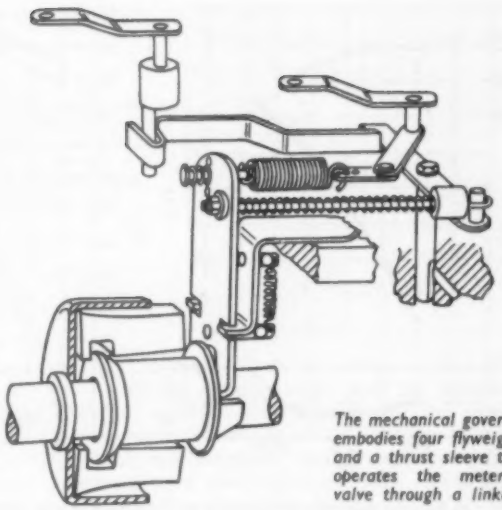
Where the more precise and rather costlier mechanical governor is specified, the pump body is longer, because of the greater dimensions of the governor unit, but the pumping unit is unaltered except in respect of the metering valve. As stated earlier, this is of the rotary type and it has an axial groove adjacent to the metering port. Pivoting about one end, the four governor flyweights are in a cruciform carrier on the driving shaft. As the weights move in or out under varying centrifugal force, they slide a thrust sleeve along the shaft. This sleeve bears on the control arm, which hinges about a knife-edge on its carrier bracket and is connected to the metering valve arm by a lightly spring-loaded hook assembly.

The main control lever is pivoted in the governor cover, with one arm outside and one inside; the internal arm is linked to the hinged control arm by the governor spring, which is in tension, and the idling spring, which is of light, compression type. It follows that the position of the control arm, and hence that of the metering valve, is determined by the balance between the pressure of the spring and the thrust due to centrifugal force on the sleeve. At idling, only the light control spring is operating, but as the control lever is moved to increase the speed, the main governor spring comes into effect. For a given setting of the control lever, any variation in speed causes an alteration in centrifugal force, and so requires a movement of the metering valve arm to restore the equilibrium.

Bearing on extension of the valve arm is a bar, moved by an external lever, which can be actuated to shut-off the fuel to stop the engine. Because of the light spring loading on the hook-up from the control arm to the metering valve arm, the valve can be shut off irrespective of the position of the governor weights and sleeve. For starting, the throttle lever is fully opened to hold the metering valve in the maximum fuel position until the engine fires, whereupon the lever is brought straight back to the idling position.

Timing Variation

As on an ignition distributor, automatic variation of the injection timing can readily be embodied in the DPA pump—a feature that constitutes one of its important advantages over the in-line pump. Such timing variation is effected by appropriate rotation of the cam ring by means of a simple hydraulic servo mechanism fed by the transfer pump. Screwed radially into the periphery of the cam ring is a ball-ended peg, which projects into the servo chamber and engages with the servo piston. This piston is spring-loaded from one end towards the retard position, and its other end is exposed to the transfer supply. A ball non-return valve in the feed line prevents the cam ring from returning as a result of impact of the rollers on the lobes, but when speed falls and the transfer pressure drops, leakage past the piston causes a movement back to the retarded position.

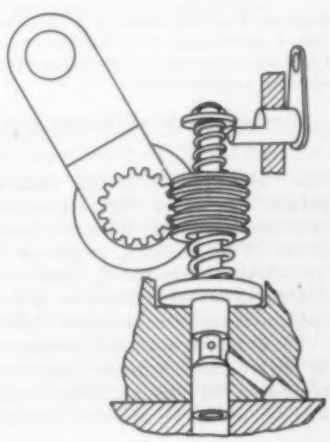


The mechanical governor embodies four flyweights and a thrust sleeve that operates the metering valve through a linkage

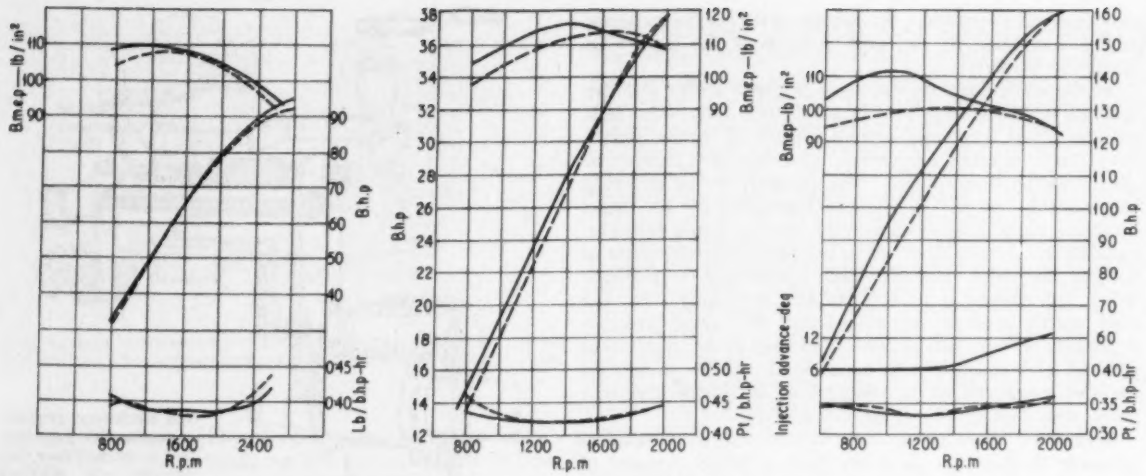
In its simplest form the timing control takes the form of an automatic advance mechanism brought into operation progressively with speed. It enables the basic timing to be set far enough advanced to give optimum torque at high speeds, without the attendant rough and noisy running which, with a pump running on fixed timing, is difficult to avoid at lower speeds. One of the sets of engine curves accompanying this article illustrates the beneficial effect of the automatic advance at both ends of the speed range. The curves were obtained on a medium-size six-cylinder unit with direct injection, in one case fitted with the DPA pump and in the other with a conventional in-line pump set to the best compromise timing.

Because a reduction in load reduces the outward travel of the pump plungers, it also causes the rollers to contact the cams nearer their crests. In consequence there is some inherent retarding of the timing as the load diminishes. The effect is analogous to that produced by variation of the contact breaker gap on an ignition distributor, and is similar to that which obtains with a conventional jerk pump with inverted-helix elements.

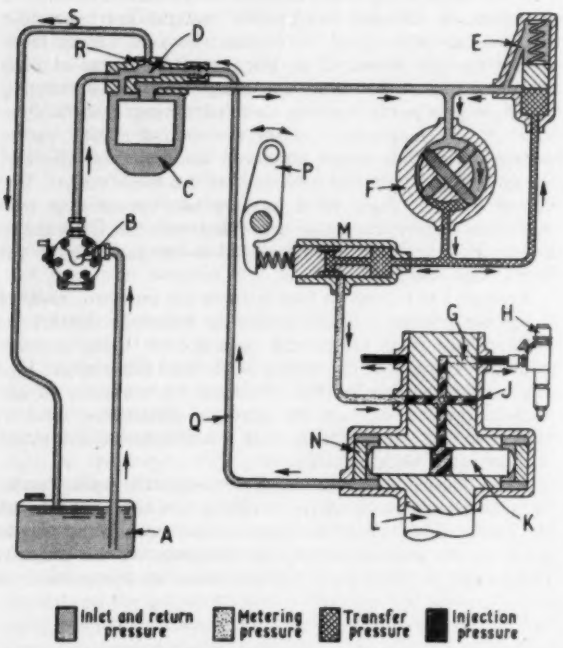
This feature tends to reduce combustion noise under light load and, particularly, at idling. In conjunction with the automatic advance with speed, it has been found to give good results and improved fuel economy on the majority of the engines tested, particularly those of the direct injection



On the simple hydraulic governor, a piston type metering valve is used, with actuation by means of a rack and springs

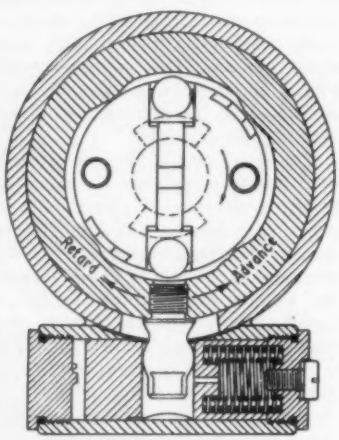


Left: Comparative performance curves of a 5 litre engine with in-line pump, dotted lines, and DPA pump with speed advance, full lines. Centre: The beneficial effect of light-load advance on the torque curve, full line, of this small, indirect injection engine is very marked. Right: Improved performance has been obtained by use of a DPA pump, full lines, in place of an in-line pump on an 11 litre engine



A *fuel tank*; **B** *feed pump with primer*; **C** *filter*; **D** *air separating chamber*; **E** *regulating valve*; **F** *transfer pump*; **G** *distributor port*; **H** *injector*; **J** *inlet ports*; **K** *plungers*; **L** *drive shaft*; **M** *metering valve*; **N** *cam ring*; **P** *control lever*; **Q** *return line*; **R** *restricting orifice*; **S** *permanent bleed*

Circuit diagram for a DPA pump fitted with a hydraulic governor



Right: The injection timing is controlled automatically by moving the cam ring. This sectional view shows the method

type. However, on certain small high-speed engines with indirect injection, the self-retarding characteristic has produced a tendency to misfire under light load at maximum speed. This misfiring could not be eliminated simply by the advance with speed, because the amount of advance needed to do so resulted in over-advance under full-load conditions and also excessive combustion noise.

To cater for such circumstances, light-load advance can be incorporated without difficulty. Use is made of the position of the metering valve, as a measure of engine load, to modify the fuel pressure applied to the servo piston controlling the cam position. The benefit of this additional control in special cases is clearly shown in the second set of curves, applicable to a 2¼ litre indirect injection four-cylinder tractor engine. By the use of light-load advance, a considerably retarded basic timing was found to be possible, and the performance at lower speeds was markedly improved as a result. The reduction of over 200 r.p.m. in the speed for maximum torque is, of course, especially valuable for a tractor engine.

In certain applications it may be desirable for the engine to produce its peak torque at a lower speed than that given by the normal pump delivery characteristics. To obtain this condition, the delivery curve can be modified by limiting the maximum opening of the control lever, but an inevitable result with this or any other type of pump is some reduction in the maximum power output of the engine.

Starting

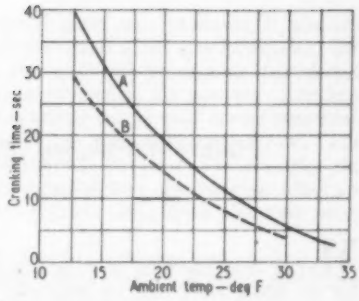
Tests at C.A.V. have shown that injection timing can have a considerable effect on ease of starting from cold. Under this condition, injection should not only begin later than during normal running, but should also terminate later in the compression stroke; the fulfilment of this requirement is regarded as being the main advantage derived from the provision of excess fuel on an in-line pump. With the DPA pump there is no additional problem to provide the

optimum retard of the cam ring for starting; control can either be automatic or by hand.

Although the provision of adequate retard, in conjunction with the usual starting aids, is normally found sufficient, excess fuel up to 50 per cent can be provided automatically if desirable on a particular engine. The method employed to provide the excess fuel is temporarily to rotate the cam ring sufficiently to cut out the normal unloading action of the cams, thereby adding the retraction volume to the normal delivery volume.

A typical fuel system for the DPA pump is shown in one of the accompanying illustrations. The main fuel filter is a C.A.V. F4 paper element unit, and the filter head embodies connections for the return line from the pump and the permanent bleed back to the tank. To lubricate the cam ring, rollers and shoes, fuel is fed, at transfer pressure, to the lower part of the rotor, by way of annular and axial grooves on the rotor; the return line to the pump permits circulation of this fuel and also serves to carry away any air entrained in the pump.

The one basic DPA pump is adaptable to engines of widely different cylinder capacities merely by varying the diameter of the plungers. There is a range of sizes from 4·5 mm to 10 mm, in 0·5 mm steps, and the maximum plunger stroke is approximately 2·2 mm. At the present stage of development, a delivery of 100 mm³ per injection is the upper limit recommended, though engines requiring greater quantities have been operating very satisfactorily during bench testing at the Acton factory of C.A.V. Ltd.



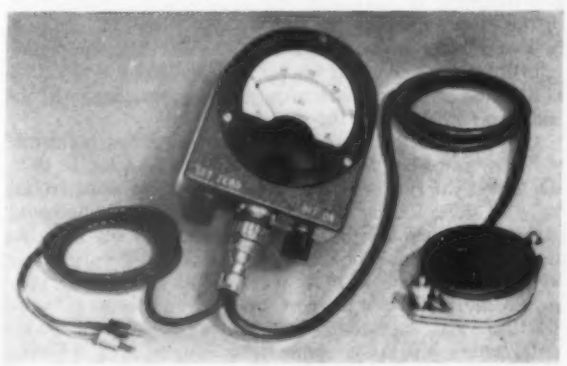
The DPA pump with starting retard, A, can provide better cold starting than the in-line pump with excess fuel, shown at B

Pedal Pressures

A NEW instrument for measuring vehicle brake pedal pressure has recently been introduced by J. Langham Thompson Ltd., Springland Laboratories, Bushey Heath, Herts. It comprises two components, the measuring head and the indicating meter, and is operated from a D.C. supply of 40 to 45 volts. The measuring head is a circular pad, 3 in diameter and 1 in deep, which is attached to the brake pedal. Within the head is a transducer element consisting of strain gauges cemented to a diaphragm and connected to form a complete bridge.

The indicating meter has its mechanical zero at the full-scale position but when it is connected electrically to the transducer element the electrical zero coincides with the scale zero. This is because the transducer is artificially unbalanced by an amount corresponding to the full pressure range of the operating pad. The application of pressure to the pad then causes the pointer to move over the scale in the normal way, but it will be appreciated that, at full pressure, the bridge is balanced and output current is nil. By the use of this basic unbalance the need for repeated service calibration of the instrument is obviated.

A pressure range of 0 to 200 lb is covered by the first model to be developed but any other maximum pressures from 50 to 1,000 lb can be obtained by modifying the dimensions of the diaphragm. The metal box that houses the meter carries the on-off switch and another for operating the zero adjusting resistance; the box is attached to the vehicle's windscreen by three rubber sucker pads on the back. A single plug-and-socket connector accommodates the cables for both the measuring head and the battery.



The Thomspon pedal pressure indicator, showing the meter and pad

Easy installation is a feature of the Thompson instrument; the time required for fitting it is only in the region of two minutes. It is expected that, in addition to its use for vehicle testing, the indicator will be of value for the investigation of operator fatigue on pedal-operated factory machinery.

RESIN HARDENERS

A NEW range of hardeners was introduced some months ago by Leicester, Lovell and Co. Ltd., for use with the company's epoxide resins. The primary purpose of the new hardeners is to reduce the toxic and dermatitic hazards that are usually associated with the normal resin and hardener combination. Extensive experience since the introduction of these hardeners has confirmed the complete absence of skin irritation troubles.

In addition to this benefit to the user, the hardeners have been found to have several other advantages. Among these are higher heat resistance in the resin when cured at room temperature, improved impact strength, smaller variation in gel time with change in temperature, less critical proportioning of hardener to resin, and ability to set under damp conditions without marked loss of strength. These characteristics should facilitate the use of epoxide resins under cold or outdoor conditions, as is evidenced by information supplied by Leicester, Lovell. Whereas with a normal type of hardener the gelling time is 3 hours at the minimum practicable temperature of 53 deg F, with the new hardener only 1½ hours is necessary at 40 deg F and 3 hours at 30 deg F. Not more than 10 per cent of the maximum strength is lost even if a casting, laminate or adhesive bond is immersed in water immediately after it is made. Further details of these hardeners and their use may be obtained from the manufacturers, at North Baddesley, Southampton.

Brittle Fracture

Failure of Iron and Mild and Low Alloy Steels, Without Measurable Deformation, Under Relatively Light Load

MILD steel has been used as a material of construction for so many years that its reliability for service under a wide range of conditions is often accepted without question, and the information provided by the tensile test is generally considered by the engineer to give a complete and adequate indication of the suitability of this material for use in any particular application. It was with something of a shock therefore that engineers learnt, from the failure of certain of the American Liberty and Victory welded merchant ships during the war years, that this material can behave in a manner not predictable by the tensile test, Fig. 1. In fact, under certain conditions, this otherwise ductile material can fail in a completely brittle manner, without measurable deformation, under a comparatively light load. The failure of the welded ships was, unfortunately, identified with welding as a technique of fabrication and while it is true that certain of the early failures of the welded ships were due, in part, to poor welding and design it is now clear that the phenomenon of brittle failure, or brittle fracture as it has come to be called, is common to all ferritic structural steels irrespective of the mode of fabrication of the structure.

One of the earliest recorded observations of brittle fracture would seem to be that by Nathaniel Barnaby who, in 1879, deplored "the fracture in Bessemer bars from some trifling blow or strain during the late severe weather at Chatham," although many years passed before there was any intensive investigation of the problem. Before considering the outcome of such investigations it is desirable, as a preliminary, to define the phenomenon more precisely. The term brittle fracture, that is, fracture with little or no prior plastic deformation, might be applied, equally, to such examples as severely work hardened steel or to hardenable steel quenched from the austenitic condition. Such brittleness, however, is immediately revealed by a tensile or bend test.

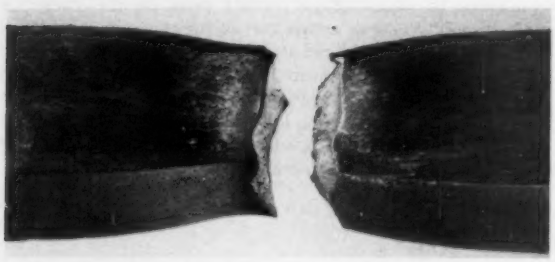
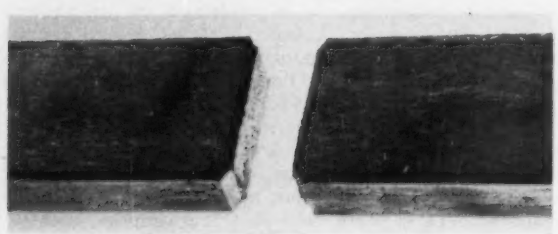


Fig. 2. Ductile and brittle fractures in mild steel test specimens: (a) above, standard specimen stressed to failure at 18 deg C: (b) below, notched test specimen that has been stressed to failure at −20 deg C



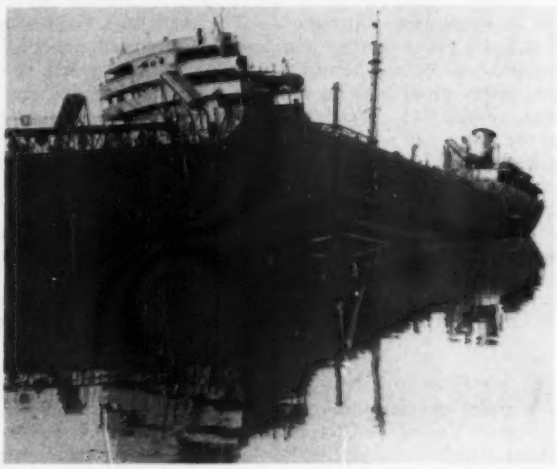


Fig. 1. This photograph is of a brittle fracture failure of the S.S. Schenectady, and is reproduced by courtesy of the Ship Structure Committee of the American National Research Council. Spectacular failures such as this have greatly stimulated research into all aspects of the problem

Brittle fracture, which resulted in the catastrophic failure of the welded ships, cannot be detected by means of the normal tensile test at room temperature, in which the rate of straining is relatively slow. The phenomenon of this type of fracture is an inherent property of ferritic materials and its occurrence is due to the fact that, under certain conditions of application of stress, fracture can take place by cleavage, through the crystals in such materials, along certain crystallographic planes, instead of by a ductile mechanism involving shear, as in a normal tensile test.

Brittle fractures normally propagate at extremely high speeds, rates as high as 4,000 ft/sec having been measured. The stress needed to extend the fracture is usually lower than that required to initiate it and the fracture surface presents a bright, faceted appearance since, as already mentioned, cleavage occurs largely across the grains, which remain substantially undeformed during the propagation of the fracture. It is usually true, also, that a test specimen taken from a plate that has failed in a completely brittle manner shows adequate ductility if tested in simple tension.

To summarize, it can be stated that the phenomenon of brittle fracture is an inherent property of iron, mild steels and low alloy steels and is the natural result of the duplex mode of deformation of these and other ferritic materials. In a normal tensile test, mild steel, for example, deforms before fracture in the manner indicated in Fig. 2a, the plastic deformation providing not only a useful insurance against fracture but also some warning of impending failure. Under certain externally imposed conditions, however, mild steel can fail as shown in Fig. 2b, without either measurable prior deformation or warning. In the example illustrated in Fig. 2b, two sharp notches were machined, in the sides, at right angles to the longitudinal axis of an otherwise standard tensile test specimen, which was then stressed in a tensile testing machine, at −20 deg C, until it failed.

It is now well established that the principal factors associated with the occurrence of brittle fracture are: low temperatures, high rates of strain and the presence of notches or stress concentrations. All ferritic steels can show a transition from ductile to brittle behaviour with decrease in temperature at high rates of strain, and for all such materials there is a critical temperature range above which brittle fracture at a notch does not occur and below which it does occur, the transition range between being narrow. This behaviour is exemplified by the typical curve, Fig. 3, which shows the energy absorbed in the standard Izod test in fracturing mild steel specimens at temperatures ranging from +50 deg C to −50 deg C. The change in the appearance of the surface of the fracture with change in the temperature of testing is also illustrated in Fig. 3, in which the transition from a dark, fibrous fracture at +40 deg C to a bright, faceted fracture at −50 deg C can be seen. From such a curve, a ductile to brittle transition temperature may be selected on some arbitrary basis.

The fundamental mechanism of brittle fracture is not, as yet, completely understood, although it is a relatively simple matter to analyze the problem itself. Thus it may be assumed that ferritic material possesses a characteristic shear, or flow, strength which rises rapidly with decreasing temperature or increasing strain rate, and a fracture, or rupture, strength which is not so influenced to any extent. Reduction in temperature increases the stress level at which flow can begin and, if this stress level is raised sufficiently, fracture will occur under conditions of high rates of strain, before flow can begin. The presence of a notch causes a local concentration of stress and contributes to the failure and, indeed, it would seem that the stress raising effect of a notch is necessary for the initiation of brittle fracture, since in order to initiate brittle fracture from a notch, however sharp, stresses slightly above the yield stress appear to be required in the general area of the point of origin.

While the phenomenon of brittle fracture is an inherent property of ferritic materials, the method of manufacture, composition and heat treatment can affect the resistance of a steel to this mode of failure. It is now well established that killed steels are less susceptible to brittle fracture than Bessemer and rimming steels; also steel of fine inherent grain size shows a lower ductile to brittle transition temperature, that is, lower susceptibility to brittle fracture, than a comparable steel of coarse grain size. However, it does not appear to matter how the small grain size is secured, and beneficial results are obtained both by suitable deoxidation practice and by an appropriate hot-working schedule. Normalizing after hot-working may or may not be beneficial, but rapid cooling lowers the transition temperature. The fineness of the metallographic structure, for example, the state of division of the pearlite, can also have an effect on the tendency to brittle fracture. Also, thick plates are more susceptible than thin.

Carbon, silicon, phosphorus, nitrogen and sulphur raise the transition temperature, that is, increase the susceptibility to brittle fracture, while manganese and nickel lower it. As a result of the realization of the relative effects of carbon and manganese, Lloyd's Register of Shipping have amended their rules* for ship plates: they have specified that, in steels to be used in ship construction, the sum of the carbon content plus one sixth of the manganese content shall not exceed 0·40 per cent.

Many tests have been devised to assess the susceptibility of steels to brittle fracture, but the exact interpretation of the results obtained is still the subject of some controversy, and the degree of correlation between the various tests is uncertain. Therefore, while a great deal is now known about brittle fracture, and many of the practical remedies for minimizing the susceptibility of a steel to this form of failure are well established, much remains to be done before the phenomenon is completely understood in all its aspects.

*Lloyd's Register of Shipping, "Extracts from the Rules for the Construction and Classification of Steel Ships", No. 4, 1957.

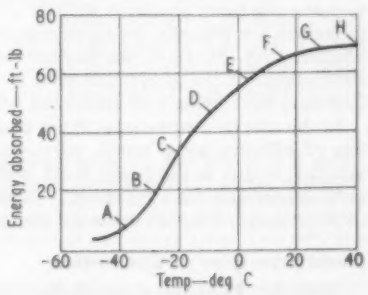
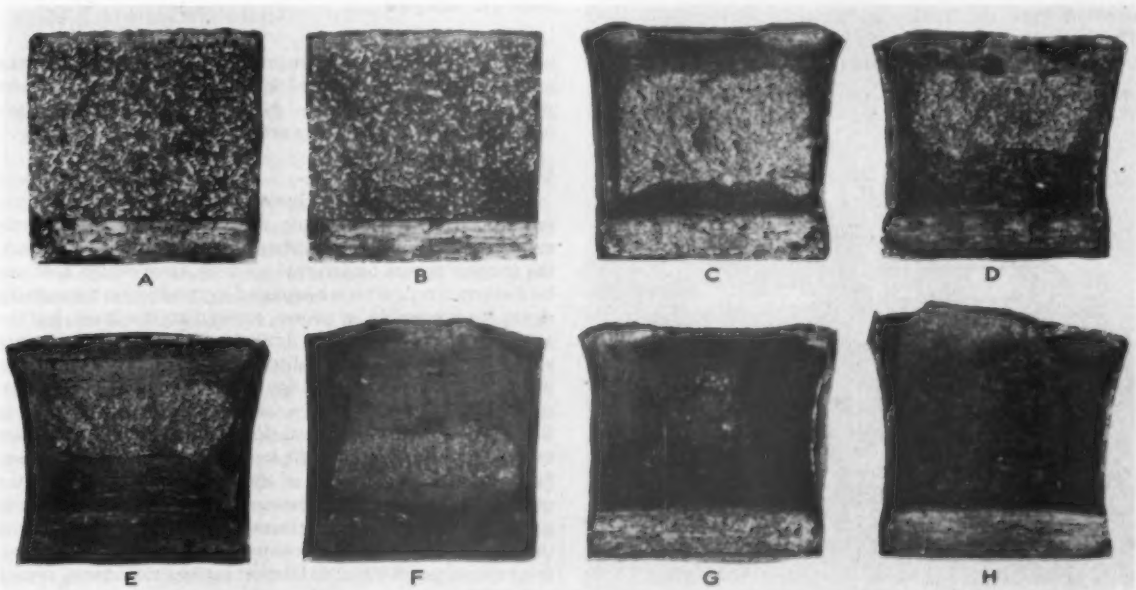


Fig. 3. The type of fracture obtained at each of the points A to H on the curve on the right is illustrated clearly below



DISC BRAKES*

Part I: Their History and Comments on Some of the Fundamental Principles

J. O. STARLING, M.S.A.E., G.I.Mech.E.

SINCE the Second World War, much thought and research has been devoted to the improvement of road vehicle brakes, particularly for heavy vehicles such as trucks, tractor-trailer vehicles, buses, coaches, and tankers. Owners and operators, especially in countries where long and exceptionally steep gradients are encountered, have for many years appreciated the need for a more efficient and comprehensive method of dissipating the heat generated during braking.

It is well known that a brake is simply a device for converting the energy of a moving body into other forms of energy mainly into heat, and that the greater the speed of the vehicle, the more heat will be generated in bringing it to a standstill. Therefore, the main problem that manufacturers are faced with is that of dissipating quickly and efficiently the heat generated, the object being mainly to avoid both drum distortion, due to expansion, and alteration of the frictional characteristics of the lining materials during prolonged or extreme braking. Obviously, the remedy for fade and heat spotting of the rubbing surfaces of the drums, and consequent judder, is to make adequate provision for the dissipation of the heat generated, for instance, by supplying cooling air around the affected parts. However, the modern trend of design towards envelopment of the wheels and axles of the vehicles seriously decreases the cooling flow round the brakes.

In the case of conventional drum brakes, a prime cause of loss of effective pedal travel, particularly with commercial vehicles, is that as the brake drum becomes hot, it expands radially outwards from the shoes. These undesirable features of drum brakes have led to the development of disc brakes.

Basic principles of disc brakes

There are two main types of disc brake. The first is the spot type. In the simplified design, shown in Fig. 1, hydraulic actuators move the friction pads into contact with the disc. These actuators are in a housing secured to a stationary part of the suspension, and the friction pads cover only a small portion of the surface area of the revolving disc. This scheme has formed the basis of many patent specifications, concerning disc brakes, filed recently, in this country and in several foreign countries by Dunlop Rubber Co. Ltd. and Girling Ltd.

A variant of the spot type disc brake has been developed almost exclusively by the Lockheed Hydraulic Brake Co. Ltd., of Leamington Spa, and by the Wingfoot Corporation of the United States of America. In this variant, only one friction pad is moved directly by the hydraulic actuator, to engage the revolving disc, the other pad being secured to the side of the housing remote from the fluid pressure chamber. In some cases the housing slides in a direction parallel to the axis of the brake disc and in others the disc itself slides, to equalize the pressures between the two pads.

An important feature of all these spot type disc brakes is that the housing containing the fluid pressure actuator-mechanisms covers only about a quarter, or even less, of the surface area of the disc. Thus, the remainder of the disc can be left exposed to the cooling air.

The second main type of disc brake is essentially similar to a clutch, in that a pair of pressure plates carrying segments of friction material, extend for 360 deg around the friction surfaces. These plates are moved axially outwards to bear against two revolving disc surfaces, usually formed by the inner faces of the drum housing them. This type of brake generally is totally enclosed by the drum, which may be ribbed for heat dissipation. Although most disc brakes are operated hydraulically, some are mechanically actuated.

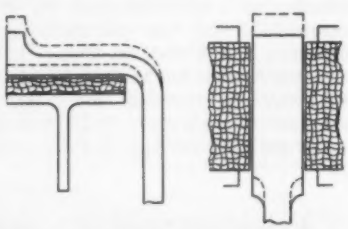


Fig. 2. The left-hand diagram shows how expansion of the drum tends to increase the shoe clearance, whereas in the case of the disc type brake, on the right, the effects of expansion on clearances are negligible

Design features

With the spot type disc brake, there are two main advantages. The first is that the friction surfaces are directly exposed to the cooling air, whereas in the drum type brakes, the friction occurs on internal surfaces, from which heat can be dissipated only after it has passed by conduction through the drum. It is possible, of course, to ventilate the drum, but the scope in this direction is limited. The second important advantage of the spot type disc brake is that, unlike the conventional drum type, the design is such that there is no loss of efficiency owing to expansion. As can be seen from Fig. 2, as the system becomes hot, expansion of a drum of the internally-expanding shoe type of brake tends to move the friction surfaces apart, causing a loss of effective pedal travel. On the other hand, brake disc expansion merely alters the relative positions of the friction surfaces slightly without tending to increase the clearance. This automatically increases the effective ratio of pedal travel to friction surface movement, since a

*Based mainly on an unpublished paper presented before the Graduate Section of the Institution of Mechanical Engineers.

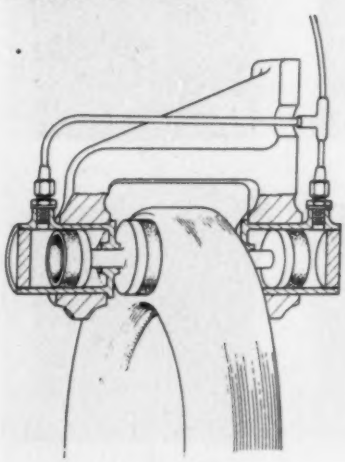
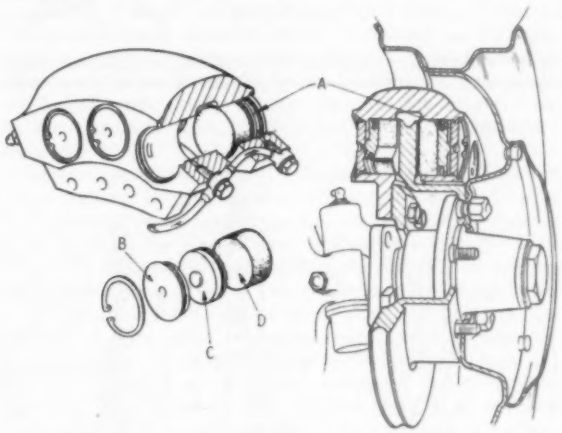


Fig. 1. Diagram showing the principle of operation of a simple disc brake

margin for expansion no longer has to be provided.

Two British disc brakes are illustrated in Figs. 3 and 5. One is a design by the Dunlop Rubber Co. Ltd., and the other is by Girling Ltd. Both brakes are of the spot type. Considering first the Dunlop type, it can be seen that a disc, which is about ¾ in thick, is gripped between horizontally-opposed pairs of circular pads of friction material, about 1½—2 in diameter and ¾—1 in thick. There are usually two or three pairs of pads, actuated by hydraulic pressure supplied from a master cylinder system. The pressure acts on opposed hydraulic pistons, one applying each pad. A housing, supported by the fixed portion of the hub assembly, embraces a portion of the periphery of the disc, usually about one quarter or less, and



A, *chambers subject to fluid pressure*; **B**, *end cap*; **C**, *piston*; **D**, *friction pad*

Fig. 3. A disc brake designed by The Dunlop Rubber Co. Ltd. In this instance, there are three horizontally opposed actuating cylinders

carries the cylinders, pistons and friction pads. The remainder of the disc is exposed to the cooling effects of the air.

It might appear from the foregoing that the brake disc would suffer from the exposure to water, mud, and other foreign matter, but even at moderate speeds, most of the mud and water that may strike the revolving disc is immediately flung off by centrifugal force. Any dust not removed in this way is scraped off by the wiping action of the leading edges of the leading friction pads and falls away, as is also the case in internal-shoe drum type brakes.

The total frictional area of the pads in this design is considerably less than that in conventional drum type brakes, the ratio being about 1:4. It follows that in disc brakes, the pressure per unit area of lining must be considerably greater than in the drum type. This may suggest that frequent relining would be necessary, owing to an increased rate of wear. However, compensating factors are that the pads can be made considerably thicker, for a given initial cost, so that more wear can take place before replacement is necessary. Another point is that friction lining manufacturers are developing new wear-resistant friction materials that may be more suitable for disc brakes than for drum type brakes.

A further advantage of this type of disc brake is that it has no servo, or self-energizing, action: therefore, the pedal pressures are directly proportional to the braking; also, braking is equal in both the forward and rearward directions of motion of the vehicle. Disc brakes of this type weigh less than their conventional drum type counterpart—a saving of approximately 20 per cent being possible.

Details of the Girling type were published in October, 1952. The design is based on that of the experimental brake exhibited at the motor show in 1951, and is similar to the Dunlop unit. Both these early systems by Dunlop and Girling operate on the Girling Hydrastatic self-adjusting principle.

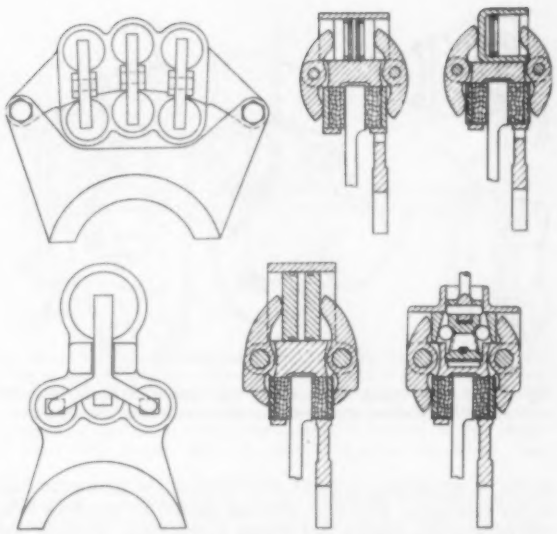
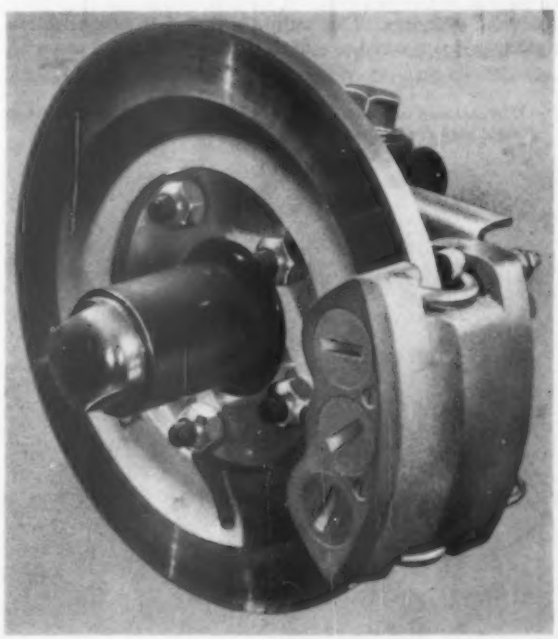


Fig. 5. Girling disc brakes adapted for mechanical operation

Return springs are not used in the actuating cylinders: when the brakes are off, the friction pads are held in light rubbing contact with the discs by both the static head of brake fluid in the actuating cylinders and, to a lesser degree, by the friction between the piston and walls of the cylinder. This has the advantage that all the pedal travel is effective, since it is not necessary to allow for wear of the friction pads.

Later developments, however, indicate that Dunlop have abandoned the principle of maintaining the pads in light rubbing contact with the disc when the brakes are off. They state that trouble has been experienced with brakes locking

Fig. 4. This half-tone illustration shows a Dunlop disc brake of similar design to that illustrated in Fig. 3. Even at moderate speeds, most of the mud and water that may fly on to the revolving disc is immediately flung off by centrifugal force; the remainder is scraped off by the wiping action of the leading edges of the friction pads and falls away from the brake



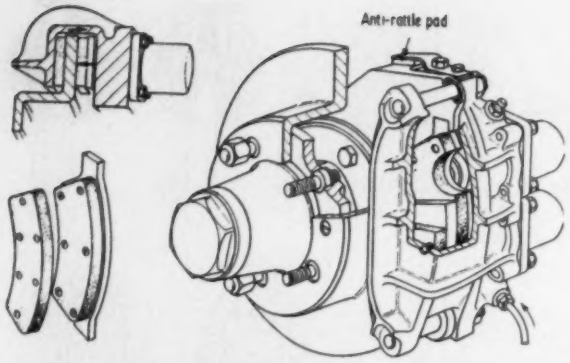


Fig. 6. An early design of Lockheed spot type disc brake, with the hydraulic cylinders and pistons on only one side of the saddle

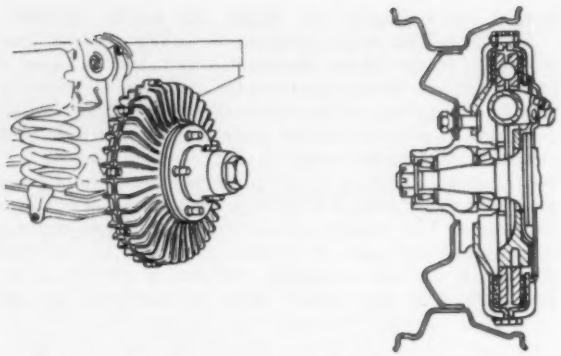


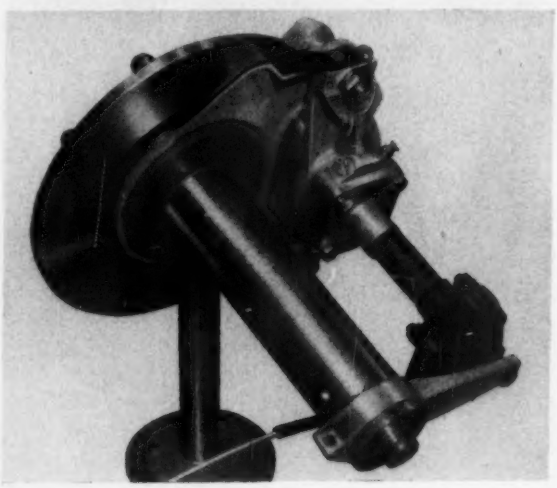
Fig. 8. The Chrysler Corporation's hydraulically actuated, internally-expanding, clutch type disc brake, which incorporates balls and ramps

in the on position, as a result of boiling of the hydraulic fluid in the cylinders. This difficulty was caused by heat flow from the pads to the pistons and thence to the fluid. Dunlop also state that power was wasted and unnecessary pad wear caused by keeping the pads in contact with the disc, so it was thought advisable to sacrifice the self-adjustment feature. On the other hand, Girling continue to use their Hydrastatic principle, and they maintain that these alleged ill-effects are not experienced with their design.

Since British law demands an independently operated hand brake, it is obvious that the designs illustrated in Figs. 3 and 4 could only be applied to the front brakes. However, hydraulically operated disc brakes have been adapted for manual operation through a mechanical linkage. Some developments by Girling in this field are illustrated in Fig. 5.

Another spot type disc brake developed in this country is that designed by Lockheed. This brake differs in many respects from the Dunlop and Girling units just described. As can be seen from an early design shown in Fig. 6, the Lockheed disc brake is essentially of the spot type, in which a pair of opposed linings is caused to grip the sides of an exposed disc. The main body of the brake consists of a light alloy casing. It is in the form of a saddle, which embraces a portion of the disc and carries both the friction linings and the brake-operating cylinders. This saddle is ribbed to give adequate rigidity and is secured to a fixed portion of the hub assembly

Fig. 7. A Lockheed single-cylinder rear brake designed for both hydraulic and push rod type mechanical actuation for hand operation



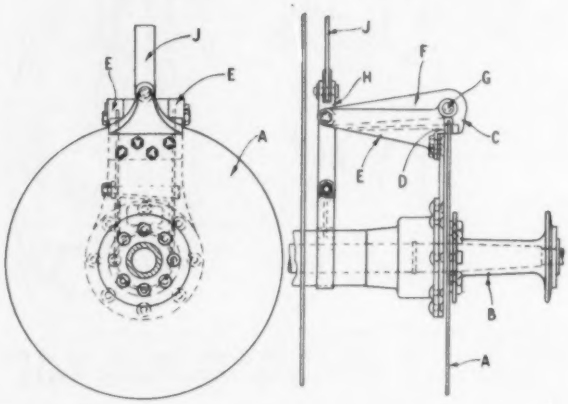


Fig. 9. Reproduction of the diagrams used by Dr. F. W. Lanchester in his specification for a spot type disc brake invented in 1902

by a rigid torque plate. It is carried on large diameter steel pins on the torque plate in such a way that it can move laterally. One segmental friction pad is riveted directly to the internal face of the saddle and the other is riveted to a carrier plate, which floats in the saddle and is located by hardened guide slots in the torque plate.

The hydraulic pistons and brake-operating cylinders are on one side only of the saddle. They operate on intermediate pads, to actuate the carrier plate, when pressure is supplied by the conventional master cylinder system. As soon as pressure is exerted on one side of the disc, the reaction causes the saddle to move axially on the steel pins and so brings equal pressures to bear on the opposite faces of the disc. Not only does the intermediate pad between the carrier plate and each hydraulic piston isolate the piston from side thrust, but also it seals each cylinder bore against the entry of dirt and moisture. The thickness of the disc is approximately $\frac{1}{2}$ in and the segmental friction pads are normally about $\frac{3}{8}$ in thick. The sum of the areas of the two friction pads is slightly less than the total area of the linings of a conventional drum brake. However, owing to the greater thickness of the pads, the actual volume of friction material is slightly greater: this tends to give longer life.

With Lockheed installations, it is usual to fit the twin operating cylinder type of disc brake at the front of the vehicle, and the single operating cylinder type, of similar design, at the rear. This single-cylinder type is illustrated in Fig. 7. It works on the same principle as the twin-cylinder type previously described. The main difference is that a push rod for mechanical actuation by the hand brake linkage, passes through the centre of the cylinder and the piston. This push

rod extends transversely into a casing mounted on the axle; the casing forms a fixed abutment for the Bowden type operating cable, which actuates a lever that moves axially in the casing.

An important feature of the Lockheed type of disc brake is that in both the hydraulic and the mechanically operated types, provision is made for automatic adjustment. These self-adjusting devices will be dealt with later.

A form of disc brake referred to previously as the second main type of disc brake, namely that working on the clutch principle, is illustrated in Fig. 8. It has been designed by the Chrysler Corporation, of America, and is a brake of the internally-expanding type. However, instead of radially-expanding shoes in a conventional brake drum, a rotating two-piece housing, which is ribbed for cooling and strength, encloses a pair of pressure plates carrying segmental linings of friction material. When the brakes are applied, these plates are forced apart axially so that their friction facings bear against the inner faces of the sides of the rotating brake housing.

Application of the brakes is effected as follows. Between inclined ramps on the pressure plates there are steel balls. Both pressure plates are arranged so that they can be rotated a few degrees by conventional hydraulic wheel-cylinders. When this happens, the balls ride up the ramps, thus moving the pressure plates apart so that the linings are brought into contact with the inner faces of the housing. This action also produces a servo effect, which assists in brake application. In this design, the actual friction surfaces are not exposed directly to cooling air currents. However, improved fade resistance is obtained by the combination of large areas of friction lining and metal surface. The increases in surface areas are as much as 30 per cent relative to a conventional drum brake.

History of disc brakes

It is commonly thought that disc brakes are a revolutionary development in brake design. This is disproved by a number of patent specifications filed early in this century. Fig. 9 is a reproduction of the diagrams used in Patent Specification No. 26,407 of 1902, by Dr. F. W. Lanchester. This is one of the first spot type disc brakes to be applied to road vehicles. Braking is effected by means of a sheet metal disc A riveted to the wheel hub B, so that friction pads on a pair of jaws C and D, when closed together, grip the outer portion of the wheel disc. One of the jaws, D, is formed near one end of a lever E, which is secured to a non-rotating portion of the wheel axle. The other jaw, C, is formed on a lever F, which is pivoted to the lever E at G. The free end of lever F is connected through a link H to a tension rod J. To apply the brake, the rod J is pulled, and this causes the jaw C to move to the left until the rim of the disc A is gripped between the jaws C and D.

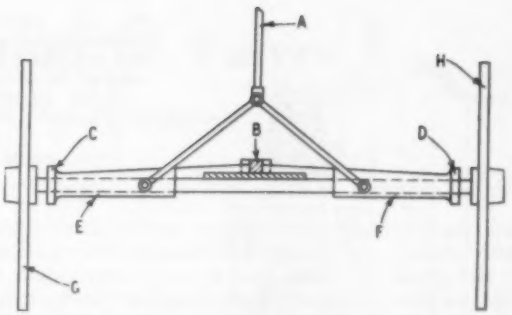


Fig. 10. In 1908, Ernst Holz was granted a patent for a clutch type disc brake to stop horse-drawn carriages in the event of the horses' bolting. When the rod A is depressed by the driver, the central pole B is disconnected from the carriage, so that the horses are released; then, further movement of the control linkage slides sleeves E and F on the axle shafts, to press the brake discs C and D against the wheel hubs

In 1908, Ernst Holz, a German citizen, was granted Patent No. 14,495/08, for an invention dealing with a clutch type, disc brake for stopping horse-drawn carriages, should the horses bolt. From Fig. 10 it can be seen that a rod A can be depressed by the driver so that the centre pole B is disconnected from the carriage to release the horses. Then, braking is effected by means of the discs C and D, at the ends of the sleeves E and F. These are slid along the axle shafts, towards the wheels G and H of the carriage, and are pressed against the wheel hubs.

The use of the spot type disc brake is mentioned in numerous patent specifications between the years 1900 and 1945. It has been applied to motor vehicles, fishing reels, gramophones, governors, railway vehicles, sewing machines, electric motors, and perambulators. However, almost all of these applications are in respect of mechanically actuated brakes, and the only cases where fluid pressure operation through linkages is described is in specifications relating to railway vehicles.

Illustrated in Fig. 11 is a disc type brake, Patent No. 387,837, taken out in the name of The English Electric Co.

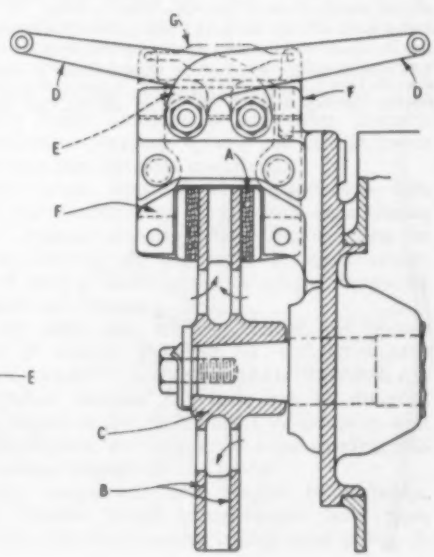
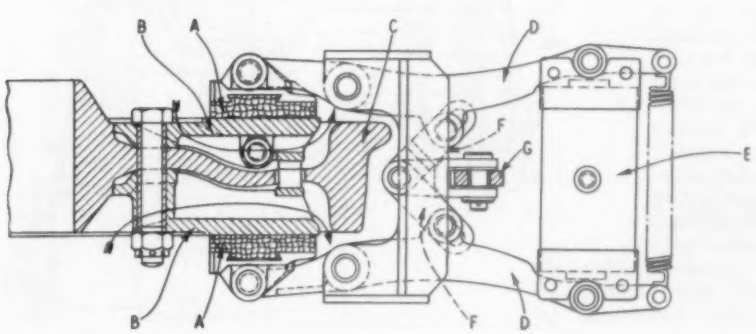


Fig. 11 Right: A disc type brake, patented in 1933 in the name of The English Electric Co. Ltd., for use on electric motor armature shafts

Fig. 12 Below: Among the early examples of hydraulically actuated disc brakes is this unit patented by the Bergische Stahl-Industrie



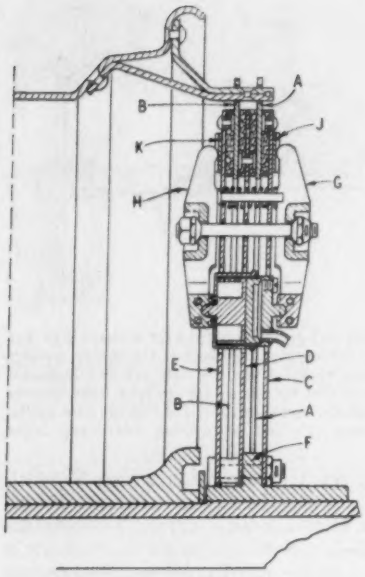


Fig. 13. Sikorsky Aviation Corporations' spot type disc brake designed for aircraft landing wheels

Ltd. This patent was accepted in 1933. As can be seen from the illustration, a brake wheel is mounted on the armature shaft of an electric motor. When the brakes are applied, a pair of brake pads or shoes A are moved towards one another, until they bear on the opposite faces of the brake wheel. This wheel comprises two perforated discs B, which are mounted on a single boss C and joined by webs to induce a radial flow of air, for cooling purposes, in the space between the discs. Upward and equal movement of levers D applies the brake by rotating the cams E, which actuate levers F carrying the brake shoes or pads A. Spring G connects the levers F, to disengage the pads.

A typical example of an early hydraulically actuated brake is Patent No. 441,665, taken out by Bergische Stahl-Industrie, Germany. From Fig. 12, it can be seen that this brake, which is applied to the bogies of railway vehicles, comprises segmental shape friction pads or blocks A engaging discs B on each side of the vehicle wheel C. The shoes A are operated either hydraulically by levers D and a fluid cylinder E, or by a toggle F operated by a lever G connected to a manual control.

In 1932, an interesting patent, No. 364,868, was taken out in the name of the Sikorsky Aviation Corporation, of the United States of America. In this, a hydraulically operated, spot type disc brake, applied to aircraft landing wheels, is described. It is illustrated in Fig.13. There are two annular discs A and B, which rotate with the wheel of the aircraft. Resilient plates C, D, and E, carrying the friction pads, are mounted on a fixed flange F. Braking is effected by the pivoted levers G and H, which apply the friction pads J and K to the outer plates C and E; in turn, these outer plates transmit the force to engage the rotating discs A and B, between which is the centre plate E, with a friction facing on each side of it.

Numerous clutch type disc brakes were patented between the years 1900 and 1945, and have been used in many applications. Two typical patent specifications of this period will be described. Patent No. 14,901 of 1908, taken out by Wearham, Riley and Ives, illustrates an application of the clutch type disc brake to cycles, motor cycles or motor vehicles, Fig. 14. The rotating disc A is secured to the wheel spokes by means of a flange B and a ring C. Its spindle D is either not of circular cross section, or it is fitted with a key, so that the boss E of a disc F can slide along it. A second disc G is mounted on the boss E, the cross section of which also is not circular, and the two discs are forced apart by a spring H. Screwed on the end of the boss E is a collar J having a cam surface, consisting of one or more ramps, on which rides cam K. This cam is fitted to a lever L. When the lever L is actuated, the discs F and G are applied with equal pressure to the disc A.

Patent No. 428,804, taken out in 1935 by the Dunlop Rubber Co. Ltd. and others, is an example of a clutch type disc brake applied to aircraft wheels, Fig. 15. The discs A and B, of non-metallic material, rotate with the wheel, being driven by splines C. Apertured metallic discs D and E are splined to the stationary hub at F. A heat-resisting disc G separates the brake disc assembly from a member H, which can be distended by fluid pressure. When the brakes are applied, the discs are forced against a reaction plate J, which is fixed to the hub and has heat-dissipating fins K. The members G and H are supported in an annular member L: this member serves as a dust-guard and is carried on a disc M, fixed to the hub. The brake can be removed after the wheel.

Fig. 14. In 1908, this clutch type disc brake for application to motor vehicles was patented by Wearham, Riley and Ives. The rotating disc B is interposed between the discs F and G, which are fixed relative to the axle D. These two fixed discs are forced apart by a spring H. The brake is applied by a face cam K and a collar J on which ramps are formed: when the lever L, attached to the cam K, is moved, the two outer discs are pressed forcibly together to clamp against the intermediate one

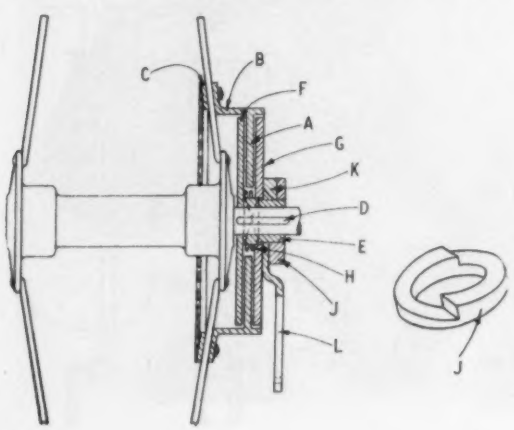
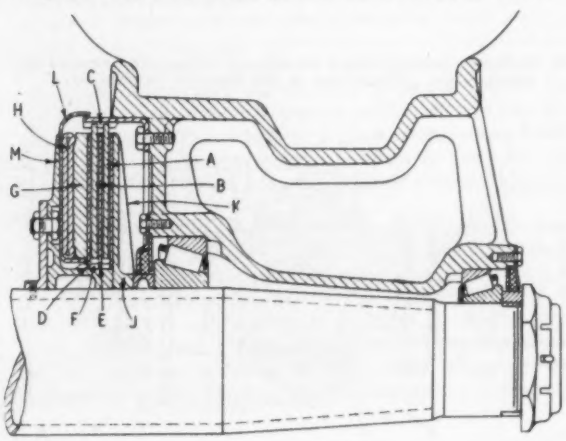


Fig. 15. An aircraft disc brake patented in 1935 by The Dunlop Rubber Co. Ltd. Rotating discs A and B, of non-metallic material, are employed in conjunction with apertured metallic discs D and E, which are splined to the stationary hub. A heat-insulating ring G separates this disc assembly from the flexible component H, which can be distended by fluid pressure to apply the brakes. The discs are forced by the component H against a stationary reaction plate J, which also is fixed to the hub



Hydraulic Operation of Valves

Some Improved Designs and New Developments

R. WARING-BROWN

BOTH direct and indirect valve operation through the medium of hydraulics have received serious consideration, investigation and trial over many years. Engine specialists and automotive engineers in general have centred interest on indirect hydraulic tappets for valve actuation; the principles, design and development of these tappets have been previously dealt with in *Automobile Engineer*, notably in the October 1945 and November 1953 issues. Since then, as a result of research and experiment, improvements have been effected and entirely new schemes have been introduced.

To the pioneers of hydraulic valve tappets, progress to date is disappointing in that no British car manufacturer has adopted such units as standard equipment, nor has any great headway been made on the Continent and in America. This is surprising in view of the fact that most of the major firms have continued to show interest in this subject. In view of the many obvious advantages of hydraulic tappets, it is difficult to understand why this principle has not been adopted more widely.

Hydraulic tappets were originally conceived as a means of overcoming noise in valve operation. Undoubtedly they accomplish this objective, because they eliminate the impact between the adjacent components of the valve gear. This they do by taking up the clearance automatically and thus maintain axial contact. In particular, they are effective in obviating the noise due to impact of the valve on its seat and the subsequent vibration.

In addition to this very important factor, hydraulic valve tappets increase the efficiency of the engine, as a result of improved timing, owing to the elimination of the clearance in the operating gear at all engine speeds, and also to the automatic adjustment once every revolution. The exact manner in which this function is accomplished is fairly well known, so only a very brief description is necessary here.

In Fig. 1, an overhead camshaft layout is illustrated. Fluid under pressure is fed from the main supply through a peripheral groove in the tappet body, and thence radially inwards through a hole to a small reservoir formed in the tappet. The hydraulic adjustment assembly consists of a cylinder fitted into the tappet, a spring-loaded plunger, and a small ball valve mounted in the base of the cylinder. When the engine valve is on its seat, the tappet spring lifts the plunger, thereby taking up all clearance and forcing the tappet to bear on the base circle of the cam. As the plunger moves upwards, under the influence of the spring, the volume of the pressure chamber is increased, and the ball valve moves off its seat to allow more fluid to flow into the pressure chamber.

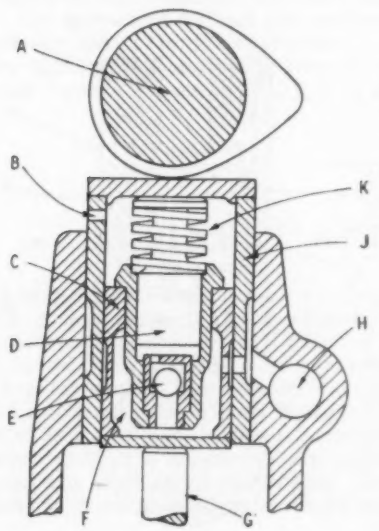


Fig. 1. Zero-lash hydraulic self adjusting tappet

A *overhead camshaft;* **B** *air vent;* **C** *cylinder;* **D** *plunger;* **E** *ball valve;* **F** *fluid reservoir;* **G** *engine valve;* **H** *fluid supply;* **J** *tappet body;* **K** *tappet spring*

Then, as the camshaft rotates, the cam forces the tappet downwards, tending to reduce the volume of the compression chamber and thereby seating the ball valve, so that the volume cannot in fact be reduced. Further rotation of the camshaft moves the tappet body downwards, since the fluid trapped in the compression chamber locks the plunger in the cylinder and tappet assembly, and thus transmits the force to the engine valve. So long as the engine valve is unseated, the load is carried by the column of fluid. During this interval, a predetermined slight leakage of fluid from the compression chamber occurs, between the plunger and the cylinder bore; this is necessary to compensate for expansion in the component parts of the valve gear. Subsequently, this leakage is compensated for by fluid passing through the ball valve into the compression chamber, to maintain the condition of zero clearance during the next cycle.

It will no doubt be appreciated that, provided the obviation of valve clearance under all conditions of engine operation can be attained and maintained, many more advantages will accrue from the employment of the hydraulic tappet. These include: (a) simplified engine design, (b) increased power output, (c) more freedom in chassis arrangement, and (d) improved durability.

(a) The use of hydraulic tappets definitely alters the conception of engine design in that it enables the manifolds to be constructed for purely functional purposes. Compromise in shape of the valve chambers, for tappet adjustment, is unnecessary, nor are removable panels essential. Further, accessories may often be positioned more advantageously.

(b) Increased power output will result from the employment of engine cam contours that exploit to the full the possibilities of zero valve clearance. Benefits can be obtained with regard to accurate co-ordination of inlet valve opening and exhaust valve closing. This will give higher compression and other desirable characteristics. Increases up to 9 per cent in power output have been obtained under test.

(c) Freedom from conventional requirements with regard to accessibility can have an important bearing on the ultimate chassis layout. Engines may be installed without any provision of tappet access. This will make it easier to provide adequate space for passengers and luggage.

(d) Durability and ease of maintenance are proven features of engines designed for and fitted with hydraulic tappets. The performance of the valves can be improved because the cams can be designed without ramps so that, operating in conjunction with hydraulic tappets, they give more rapid opening and lower seating velocities of the valves.

As previously mentioned, new designs of hydraulic tappets, with definite detail improvements have been introduced. One such improvement is illustrated in Fig. 2.

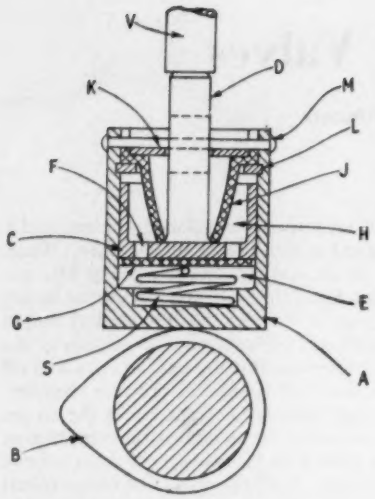


Fig. 4. Cross section of the Buckley hydrostatic tappet, showing the sealing device

A substantially incompressible liquid is confined in the lower end of a tappet body A by a piston P, which however, permits a slow leakage to the upper end. The tappet head is formed by the plunger B sliding in a cover C, and is provided with a spider head seating on an internal flange in the piston. Bellows D, attached to the head of the plunger B and also to the cover C, seal the sliding joint.

When the tappet is raised by the engine cam K, a small amount of the fluid is forced past the piston, so that there is a positive clearance to ensure that the engine valve seats properly when the tappet falls. During the idle period, the spring S raises the piston again, and fluid is drawn, through an aperture in the piston head, from the upper to the lower side of the piston. A disc valve H regulates the flow through the aperture. The felt filter F, supported on a gauze screen E, prevents the introduction of air bubbles into the lower chamber.

Initially, the fluid is introduced through a small hole in the top of the plunger B, which is subsequently closed by a plug G. From this it is evident that the aim is at the elimination of the conventional force feed system from the scheme. This may prove advantageous under certain circumstances.

An important aspect of the design of hydraulic tappets is the elimination of air or gas that may be trapped in the system. The scheme illustrated in Fig. 3 has been devised to solve the problem. An engine cam is shown at A, and B is the push rod for an overhead valve gear. Tappet C has a cylindrical sliding body, the lower end of which is in contact with the engine cam. Its upper portion is bored to receive a piston D. Fluid under pressure, from the engine lubrication system, enters through the port E and then passes in through a radial hole F and a one-way ball valve H. Thus the whole of the interior is filled with fluid.

In the unloaded state, of the tappet, a spring J elongates the assembly to take up the clearance, while at the same time fluid passes the ball valve into the lower chamber K. On the upstroke of the tappet, the fluid trapped in the chamber K transmits the thrust to the piston and thence to the push rod. Any gas trapped in the system will collect in the top of the piston, and can escape, during the unloaded periods, through the small vent L. The whole assembly tends to rotate slowly owing to a slight offset of the engine cam relative to the axis of the tappet. This is to centrifuge the air towards the centre.

Another design feature worthy of consideration is that illustrated at Fig. 4. Self-adjusting hydraulic valve tappets of course, require an infallible sealing device, because the loss of even the most minute quantity of fluid may upset the adjustment. The seal must be capable of withstanding rotary motion because in many instances the engine cam imparts a slight turning moment to the tappet.

From the illustration it can be seen that a cylindrical tappet body A is lifted by the cam B, and this motion is transmitted hydraulically to a piston C, the stem D of which actuates the engine valve V. The chamber E in the bottom of the tappet body is filled with fluid. A small quantity of this fluid escapes past the piston at every stroke, but is subsequently replenished, through the ports F and a disc type non-return valve G, from the reservoir H formed between the piston and the sealing device. This seal comprises a flexible cup J clamped between two rings K and L and secured in a fluid-tight manner to the piston stem. To

Fig. 2. Borg-Warner hydrostatic tappet

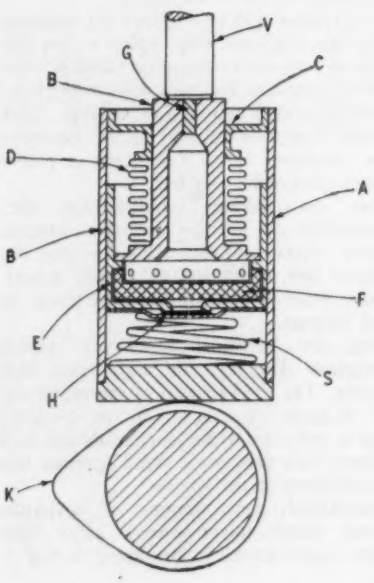


Fig. 3. General Motors Corp. hydraulic tappet

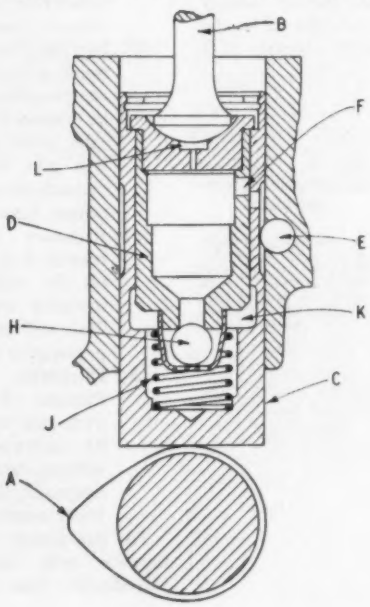
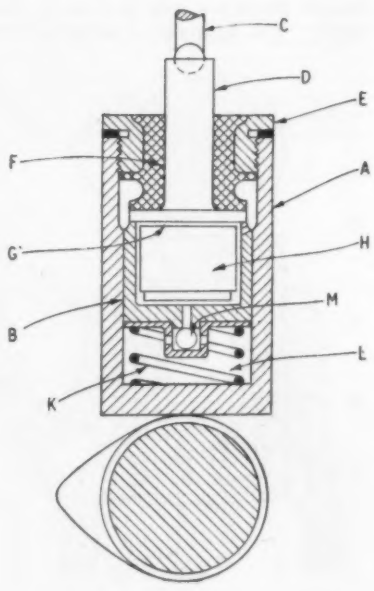


Fig. 5. Renault patent hydrostatic tappet



prevent rotation of the assembly, a pin M is passed through a diametral hole in the tappet body and a slot in the piston stem D.

An interesting hydraulic valve tappet is that illustrated in Fig. 5. It gives a constant working clearance, and requires no attention because it is sealed permanently during manufacture. The principal components are a cylindrical body A, on the lower end of which the engine cam bears, and a piston B, an extension of which receives the engine valve stem, or push rod C. The extension of the piston D, together with a screwed cap E in the top of the cylindrical body A, is sealed against leakage by a synthetic rubber sleeve F, to which they are bonded. This sleeve is sufficiently soft to permit a slight relative movement during automatic adjustment. A chamber G in the piston houses a gas-filled rubber block H. This chamber is connected with a compensating chamber L, which is filled with fluid. A helical spring K keeps the unit expanded, to take up all slack.

When the tappet is loaded, the fluid in the chamber L is under pressure and the ball valve M is closed. The assembly then is virtually a solid member, except inasmuch as there is a slight leakage between the body and the piston. This leakage provides for compensation for thermal expansion and contraction. The leaking fluid passes into the chamber G, and drains back through the ball valve when the unit is no longer loaded.

Whereas all the designs so far dealt with, whether hydrostatic or engine operated, have been constructed to act in line with and directly upon the engine valve, it is also practicable to incorporate the hydraulic mechanism on the valve lifter or, in the case of push rod operated overhead engine valves, on the rocker. This has the advantage of robustness of construction and improved accessibility.

A self-adjusting valve of this type recently put forward is that illustrated in Fig. 6. The clearance is taken up by means of a hydraulic adjuster, the pressure originating in the engine lubrication system. Rocker A is mounted on a bush F which is eccentrically bored. It is pivoted upon a spindle G, which is the common pivot for all the rockers actuated by the push rods H. Attached to the eccentric bush is a lever B, which adjusts the clearance by raising or lowering the pivot axis of the rocker.

The lever is actuated by a piston C, in a cylinder E connected to the engine lubrication system. In the connection there is a non-return valve D. When the engine is stationary, the piston is near the right-hand end of its cylinder, but as soon as the engine starts, the fluid pressure moves it to the left, to take up all the clearances. This movement is very small and occurs only when the engine valve is closed.

The proportions are such that the fluid pressure cannot possibly open the engine valve against its spring K. When the engine valve is opened, the piston C cannot move to the right because the one-way valve D is closed. When the engine stops, return movement of the piston can occur slowly as the fluid leaks past the piston and drains through a small hole to the crankcase. To allow for the high viscosity of cold fluid, the piston is made of high expansion alloy, so that the clearance, and therefore the rate of leakage, is increased when the engine is cold.

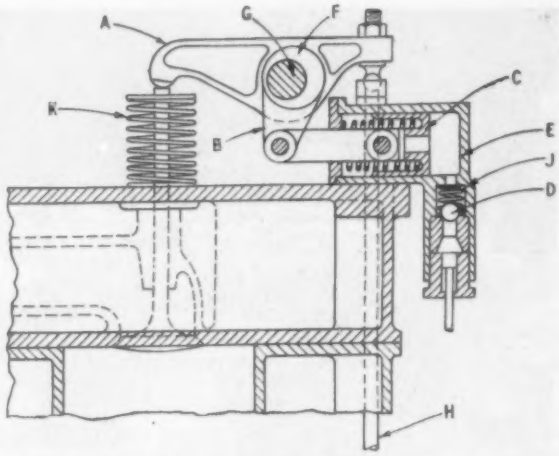


Fig. 6. This Daimler Benz hydraulic adjuster actuates an eccentric bush on which the rocker is pivoted, and thus takes up the clearance

Evidently, the problems involved in the perfection of hydraulic valve tappets are being thoroughly investigated, and tappets of this pattern may soon become more widely adopted. It is the author's view that two factors in design have not received the attention they merit. The first is the variation of the effect of both ambient and working temperatures on the properties of the operating fluid. It is suggested that fluids similar to those used in brake and suspension units might be employed. This might overcome difficulties, owing to changes in viscosity of the fluid, with regard to erratic action in normal running and difficulty in starting.

For perfect operation of the hydraulic valve mechanism, where working clearances are at a minimum and valve ports, holes and passages are restricted, it is highly desirable that the fluid should be clean and free from particles. Although the modern automotive engine is usually equipped with apparently highly efficient filters, it is well known that fine particles do get through, and these can be sufficient to prevent consistent action of the hydraulic valve. This difficulty might be overcome by adopting a completely separate hydraulic system, including a small reservoir, filter and pump unit. The pump could be of fairly small dimensions and of a simple type, driven from the engine camshaft. The extra cost would not be exorbitant.

BUSINESS AND SPECIALISED PUBLICATIONS

A BOOKLET entitled *Business and Specialised Publications of Great Britain* has just been produced by The Public Relations Committee of the Council of The Trade and Technical Press. It is intended to meet what is believed to be a long-felt want for concise information about the business and specialized press of Great Britain. The work contains brief details of journals, listed in alphabetical order, together with, in a separate section, similar details of year books and other annual publications. At the end will be found an index, classified under subject matter, where those concerned with a particular sphere of activity can find grouped together the publications likely to be of most interest to them.

All the journals listed in this booklet are in membership of the Trade and Technical Press, which is a section of the Periodical Proprietors Association. They fall under a variety of headings, technical, trade, professional, specialized and export, and range in frequency of publication from weekly to quarterly. Copies of the booklet can be obtained from the Council at Imperial House, Kingsway, W.C.2.

General view of the erecting bay at James Whitson and Co. Ltd., showing Peerless sports cars in varying stages of completion

Peerless Sports-Car Body

Production Methods Employed for the Manufacture of an Interesting Four-Seater Saloon of Glass-Reinforced Polyester Resin

WHEN a prototype of the Peerless *gran turismo* four-seater sports saloon was exhibited at the 1957 Paris and London Shows, it had a well styled aluminium body, but when production began, which was in May 1958, a polyester-glass fibre body had been developed instead. This vehicle, which is powered by the 2-litre Triumph TR3 engine, is produced by Peerless Cars Ltd., of Slough.

Consultations with James Whitson and Co. Ltd., of Yiewsley, Middlesex, regarding a polyester-glass fibre body for the Peerless G.T. started in February 1958. The chairman and managing director of this company, Mr. A. E. Whittit, has over forty years' experience of coachbuilding. During 1957 Whitsons had amassed considerable knowledge of plastics moulding technique, since they produced 250 bodies for the Coronet three-wheel vehicle. Now, their faith in polyester-glass fibre for automobile applications is such that they have abandoned the traditional methods of construction. Their current activities also include the production of plastics cabs for commercial and milk-delivery vehicles, dash facias for Citroën cars, street lighting lamp covers, detergent tanks and litter bins.

Preliminary discussions in respect of the Peerless car indicated that the body could be constructed more lightly and cheaply with polyester-glass fibre than with aluminium: the high cost of the raw materials would be more than outweighed by the reduced charges in respect of labour, as compared with those for panel beating. In March of last year, Peerless Cars delivered an aluminium-bodied prototype and body mock-up to Whitsons for work to begin. Although the basic shape of the plastics body is much the same as that of the original, numerous changes were made both to improve the appearance and to facilitate production in the new medium. Work progressed rapidly thereafter and the first three cars were completed towards the end of May—a creditable effort.

Experience gained during the development and production

This three-quarter front view of the Peerless G.T. car emphasizes the low build and slight curvature of the waistline. Wrap-round bumpers are employed

of the Coronet suggested that, to avoid surface undulations, bonded-on wood or metal should be used as little as possible for reinforcement of the plastics, and also that a composite structure was undesirable. The consequent necessity of making virtually the complete body in polyester-glass fibre dictated a multiplicity of mouldings—57 in all. By that means, the construction of individual moulds was simplified and production of the mouldings was kept within the scope of the personnel available. An idea of the size and disposition of the various component mouldings is given by the accompanying reproduction of an artist's drawing.

Where possible, female moulds were prepared directly from the modified mock-up, but where this could not be done, male masters were made in wood, metal or plaster and female moulds taken from them. Following normal practice, the moulds were made of polyester-glass fibre, using four or more laminations of 1½ oz random mat. After being left for an ample time for hardening, the moulds were reinforced, as necessary, to avoid flexing, which would give rise to imperfect mouldings. Much importance is attached to the reinforcement, and plywood laths and steel strip and angle are among the materials used for the purpose.

For some of the smaller components the time cycle is such that only one set of moulds is needed, but for others, more than one is required. With the recent introduction of a second set of moulds for the main portion of the body, the production potential has been increased to 10 units a week, and will rise to 15 when a third set is completed. To simplify laying-up, there are five parts to the body-shell mould: two full-length sides; the top which, extending from the nose to half-way round the boot, is the largest single mould; and the lower portions of the nose and tail. For bolting together, the mould sections have peripheral flanges into which are bonded steel bushes. The bores of these bushes are reamed to ensure a good fit of the attachment bolts and hence accurate location. Most of the component moulds are of the one-piece type but, to facilitate withdrawal of the mouldings, two-piece moulds are utilized for the instrument panel and for the boot interior, which embodies the spare-wheel pan.

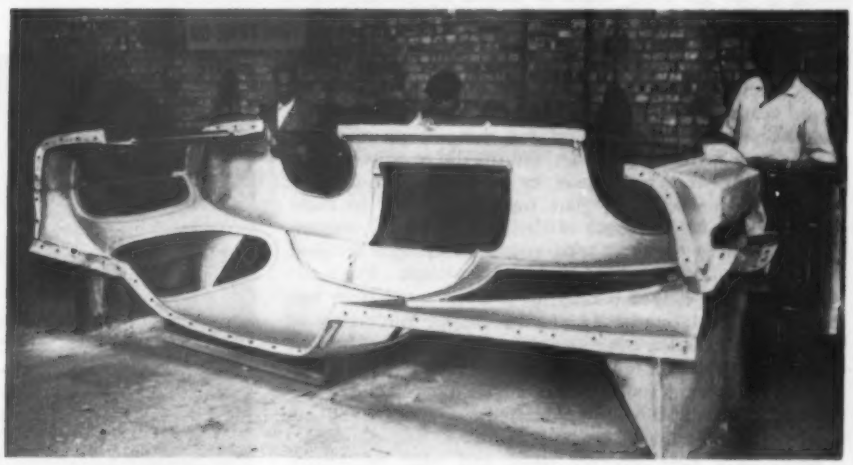
Turning now to the actual production, the 1½ oz random glass mat is pre-cut to pattern—a method which minimizes waste—and a set of mats is issued for each body. One man is responsible solely for the preparation of the polyester resin which is normally mixed in five-gallon batches, less catalyst, and allowed to stand overnight to permit the escape of most of the air trapped during the mixing process. Working quantities of 7 to 10 lb are drawn as required and catalyst is added immediately prior to use. With one exception, to be mentioned later, the resin is not pigmented. This is because of the difficulty, with small-scale production, of estimating the quantities of any given colour likely to be ordered. For resin layers other than the gel coat, 20 per cent of filler is employed; and for mouldings where flow is likely, a proportion of thixotropic resin is added.

Method of laying-up

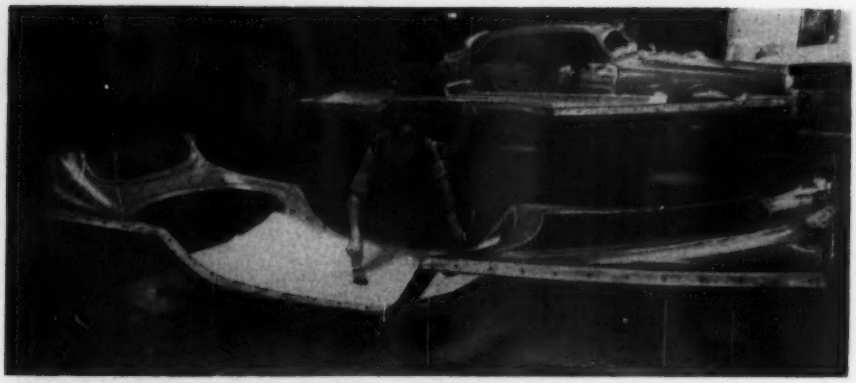
To ensure satisfactory curing, all laying-up of mouldings is carried out in a large bay maintained at 60 to 70 deg F, with controlled humidity. Atmospheric curing is usually employed, but for smaller mouldings the process can be accelerated by means of an oven heated to 120 deg F. Mouldings that are not oven treated remain in the moulds overnight and are then stood for a minimum of ten days to harden. To reduce the time that the main body moulding remains in the mould, a system of infra-red lamps is now coming into use.

Some of the operators are engaged on the laying-up of the smaller components, while the others are formed into teams for the production of the body shells. The moulds are first cleaned thoroughly and examined for surface defects before being wax polished and coated with a polyvynyl-alcohol release agent. Then the gel coat of resin is applied and allowed to set for 30 min or more, according to the nature of the moulding. After the gel coat has set, a coat of filled resin is brushed on, and then a layer of mat is applied. More resin is added and is worked in by means of hand rollers of the "washer" pattern. The need for thoroughness in the rolling, to obtain full impregnation of the mat and the exclusion of air, is impressed on all operators. A second laminate of glass mat and resin is applied after the first has partially set. Additional laminations are applied at more highly stressed localities: for this purpose, off-cuts are used, to reduce waste. Where necessary, edges are strengthened with rovings. Because of the time taken to apply resin by hand, the possibility of using spray equipment is being investigated.

Each morning the five body moulds are laid-up separately, with the mould horizontal to minimize resin flow. The mats are slightly smaller than the moulds so that a border of about 1 in is left all the way round. During the afternoon the moulds are bolted together and the mouldings are united by laminating across the gaps, with 6 in wide strips



Reinforcement being carried out on a new set of female moulds for the body shell, to ensure freedom from distortion



Laying-up the body top with pre-cut glass mat and resin. The top is the largest single moulding used in the car

of mat. At this stage a $\frac{1}{16}$ in diameter steel tube is bonded into each windscreen pillar, where the top and side mouldings meet. The tube not only serves as a reinforcement but also provides a conduit for the interior lighting cables. To withstand the stressing, considerable glass reinforcement is applied at the base of the screen pillars and the rear-quarter pillars.

Two men on early turn, at 7 a.m., release each shell from its mould, label it with the date of production and affix a variety of wooden and metal formers and struts to prevent any sagging before the moulding has hardened. During the hardening period the shell is carefully examined for pin-holing of the gel coat, which is caused by included air. Any such pin-holing is cleaned out and filled before the later painting stage.

The exceptions to the use of non-pigmented resin are the corner bumpers: for these, aluminium powder is mixed with the gel coat to give a silver finish. It is not without interest that the original intention was for these bumpers to be chromium-plated steel pressings, but the die costs quoted by outside firms were prohibitive in view of the quantities involved. Four layers of glass mat are utilized in these components which, because of their deep channel section, are regarded as being at least equal in strength to steel bumpers of normal gauge.

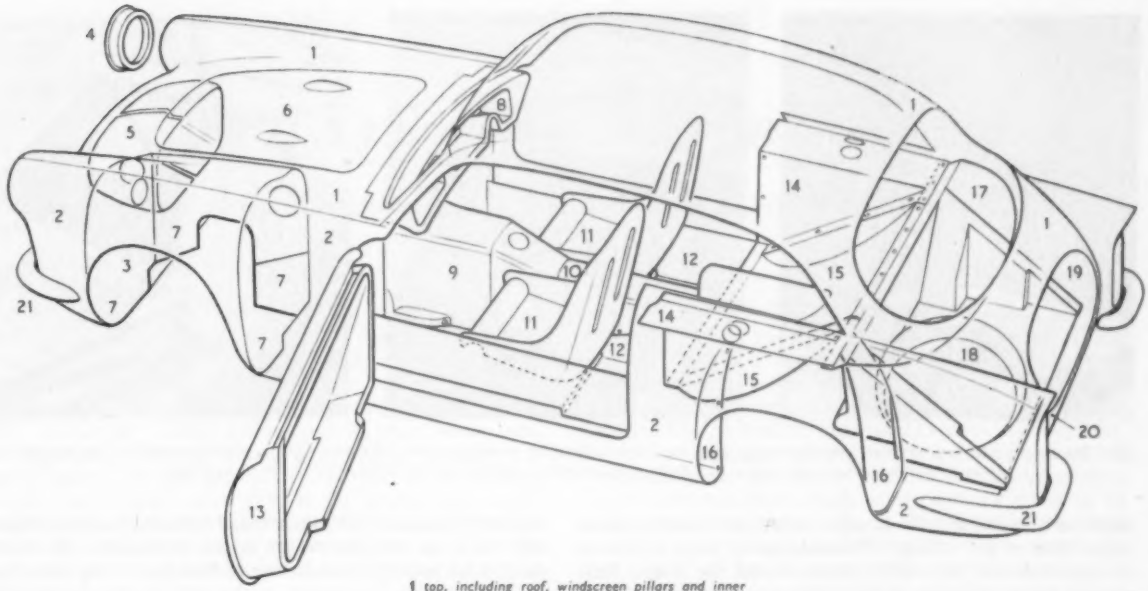
The frontally hinged bonnet lid is constructed from two mouldings, amalgamated by pressure before the resin has set. Embodied in the upper moulding are two small humps of streamline shape, one to provide clearance over the forward carburettor and the other to give a balanced appearance. The lower moulding incorporates a stiffening rib of semi-circular section near its periphery.

Both doors have separate panel and edge mouldings, bonded together, and each is braced by a steel triangulated structure bonded to the forward edge and the bottom. The base and perpendicular side of the triangle are, in effect, a wide angle-bracket, each arm of which has a shallow stiffening flange on its outer edge; the angle has a small gusset for additional rigidity. Between the ends of the arm flanges is welded a channel-section stay which completes the triangulation. To avoid surface irregularities of the door panel, the stay is not bonded to it. The hinge arms of the doors are welded to a steel plate, which is bolted to the bracing structure, the bolts being passed through the forward edge of the door.

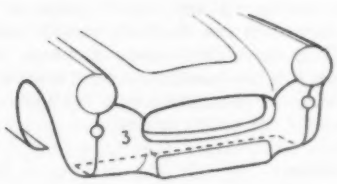
The boot interior flooring trays and the transmission

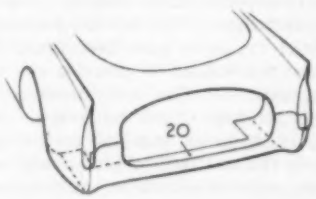
Above: Female labour is employed on some of the laying-up work. The corner bumpers comprise four layers of mat

Left: After each body shell is removed from the composite mould, stiffeners are fitted and the shell is allowed to harden for a period of at least ten days



1 top, including roof, windscreen pillars and inner portion of all four wings; 2 side panels, full length, one each side; 3 lower front section; 4 headlamp holders, one each side; 5 radiator air intake, two parts; 6 bonnet top, double moulding; 7 front wheel arch, four parts each side; 8 facia panel; 9 gearbox cover; 10 propeller shaft tunnel; 11 front seats; 12 floor trays, one each side; 13 doors, three parts each side; 14 rear wheel arch inner trim panels, one each side; 15 rear seat pan; 16 rear wheel arch, two parts each side, forward one detachable; 17 parcels shelf; 18 boot interior and spare wheel pan, three parts; 19 boot lid; 20 lower rear section; 21 bumpers





The line drawings reproduced above illustrate the major plastics mouldings from which the Peerless body is constructed. Metal is employed to reinforce the windscreen pillars and the structure of the doors, also for the roof bracing pillar on each side

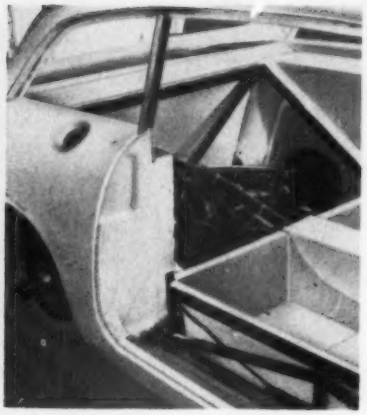
tunnel are fitted to the chassis before the body is offered up—the first of necessity and the others for convenience. Initial attachment of the mouldings is by pop-riveting to the square-section tubing of the space-frame. Where the loading warrants it or a neat appearance is required, the joints are reinforced by laminations of resin and glass mat. This treatment is not needed in the case of the floor, because the flanged upper edges sit directly on the chassis tubes, and therefore the rivets are not loaded in shear.

Primary attachment of the body to the chassis, too, is by pop-riveting followed by bonding. The door hinges are carried on two steel-sheet half-bulkheads previously pop-riveted to the scuttle structure. These half-bulkheads are shaped at their outer edges to conform to the curvature of the body sides, to which they are bonded. Further stiffening is effected by the front wheel-arch mouldings and also by the door shut-pillars, which are attached to the forward vertical members of the rear structure of the space-frame to form bulkheads. The shut-pillars form the forward faces of the rear-wheel arches, and other mouldings mate up with the boot interior panelling to complete the arches. A carrier for the battery is installed in the left-hand rear end of the body, between the diagonal wall of the boot and the body side. To prevent entry of moisture from beneath the car, rubber-base sealing compound is applied at all critical points between the chassis tubes and the mouldings before pop-riveting is carried out. The riveting technique has not given rise to any trouble through crushing of the relatively soft plastics material.

To brace the roof, a steel strut is fitted immediately behind each door shut-pillar. This strut is of T-section between the waistline and the top of the window opening and is bonded to the roof, to the pillar and to the bottom of the body. Holes are drilled in the steel strut to ensure that it keys to the plastics pillar. For the roof guttering, which extends from the base of the screen pillars to that of the quarter pillars, light-alloy extruded J-section is employed and is pop-riveted to the turned-in flange on each side of the roof.

Other mouldings fitted after the body is mounted on the chassis include the instrument panel, which embodies a

Two moulds are used to make the boot interior and spare wheel pan. The battery is housed in the rear section of the left-hand wing



Left: The bonnet lid comprises two laminated mouldings, the lower embodying a stiffening rib. Centre: A single plastics moulding, upholstered in foam rubber, constitutes the rear seat. Right: The bodysides are pop-riveted and bonded to the space frame

large cubby hole, and the interior panelling of the air intake at the front of the vehicle. The instrument panel is bonded to and reinforces the scuttle structure and the body. Self-tapping screws are used to attach the nose ducting sections; this is to permit their removal for access to the heater fan, mounted ahead of the left-hand wheel arch.

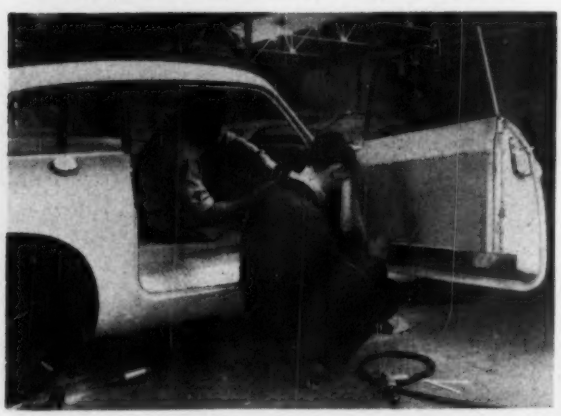
After the doors have been fitted, the light-alloy window frames are bonded in position and the locks and winding gear installed. The door structure is then completed by the attachment of the inner skin. Hinges for the framed quarter lights are attached to the light-alloy sections that box-in the two roof pillars already mentioned. The windscreen and rear window are set in rubber in the usual manner, and a stuck-on rubber sealing strip draught-proofs the edges of the door closing area in the body sides.

Petrol tank stowage

Each of the two petrol tanks is of 7 gallons capacity and is of steel construction. They fit into the space between the chassis side-members and the body sides, below the door, and rest on off-cuts of the carpeting material. Since they are located longitudinally and are a close fit in their compartments, no means of attachment are necessary. The tanks are concealed by the door sills, which are of aluminium chequer-plate held down by self-tapping screws. Each tank has its own filler neck extending up to a large quick-action filler cap carried in the body side above the rear wheel.

Attachment of the bumpers, with rubber buffers interposed between them and the body, completes the main construction, and the car is then transferred to the paint shop. After the doors have been checked to ensure that they hang correctly, the body is freed of grease marks and rubbed down with wet-or-dry paper before being given a spray coat of resin-base primer, which shows up any imperfections of the surface. These are remedied and the body is again rubbed down prior to receiving three spray coats of colour, using a synthetic gloss paint that has been found most suitable for use on polyester resin. It has qualities of flexibility that correspond with those of the body material.

Later stages: one man covers the facia panel with vinyl fabric, while another fits the aluminium rubbing strip inside the door



Trimming and seating

When the painting is completed, the car returns to the main assembly bay, for the installation of the lighting equipment, trimming and the fitting of the seats. A layer of felt insulation is laid over the transmission tunnel and then it and the floor are covered with black carpet. The trim between floor and roof is grey p.v.c. coated fabric with a leather graining. A thinner, ungrained p.v.c. material is employed for the head lining; initially it was stuck to the roof but this proved unsatisfactory and it is now listed on transverse steel wires. For the instrument panel, black grained vynyl-coated material is applied over a layer of foamed plastics. The lip of each door cubby hole is trimmed with a polished aluminium strip, which serves to prevent damage by occupants' shoes as well as giving a decorative effect. The whole of the boot interior is finished in matt black paint.

Cutting of the carpeting and trim materials is carried out in a separate shop, in which the upholstering of the seats is also done. Each bucket type front seat is a single polyester-glass fibre moulding with two ventilation slots in the back; the rear seat, too, is a single moulding and is of pan shape with an integral arm rest. All the upholstery is in pleated grey leather, matching the trim, and the front seats have moulded foam rubber cushions and padded squabs. To give maximum headroom, with a low roof line, the rear seat cushions are a 2 in thick layer of foam rubber. The front seats are carried on orthodox floor-mounted slides and the occupants' weight is transmitted directly to cross-members of the chassis. Since the rear seat pan has to be removed for access to the axle, it is secured by four self-tapping screws to the inclined tubes at each side of the chassis.

Thorough interior cleaning and exterior polishing are the only remaining stages in the production process. When they are completed the vehicle is handed back to Peerless Cars, for road testing and a final check prior to delivery.

TRAILER PROGRESS

A Review of Recent Interesting Developments in Respect of Trailers and Semi-Trailers

IT was obvious at the 1958 Commercial Vehicle Exhibition that considerable activity has recently taken place in the design departments of firms concerned with trailers, and especially with semi-trailers. There are two parallel directions of development that are being followed in the car and commercial vehicle fields, namely, disc brakes and air suspension. Efficient braking, is of course, essential on a trailer and is, perhaps even more vital than on the tractor vehicle; any marked inferiority on the part of the trailer brakes can give rise to jack-knifing and similar troubles. Thus, there must be ample opportunity in this field for advantage to be taken of the performance superiority of the disc brake.

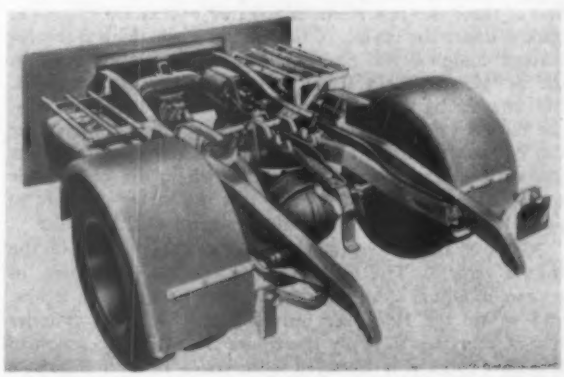
There is an equally sound technical reason for the adoption of air springing. This is its facility for the automatic adjustment of characteristics to suit either the heavily loaded or empty condition of the trailer. Because of its lack of an engine and other equipment, a trailer inevitably has a higher ratio of laden to unladen weight than has a lorry to carry the same weight.

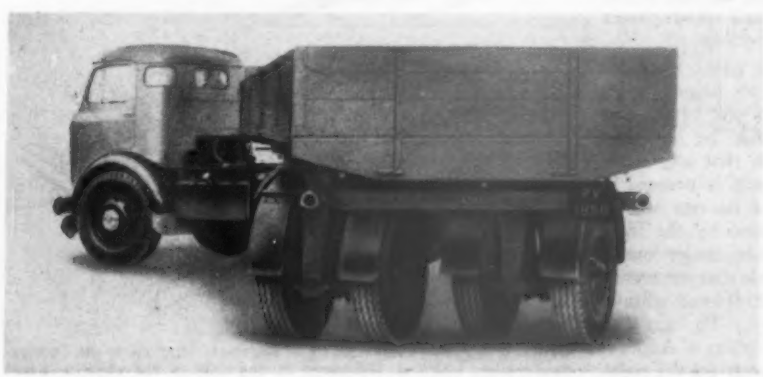
On a semi-trailer with a four-wheel bogie it is attractively simple to use one long air bag at each side of the bogie as a common spring for both axles. This allows one wheel to rise while the other falls or remains steady. Further, the necessary distance-member between the two axle beams can be hollow and so can serve also as a surge tank, or air chamber, to provide a desirably low periodicity for the spring.

In such designs, provision for relative transverse angular motion between the two axle beams has sometimes been made by the use of rubber mouldings, which can distort to allow this movement. From a purely mechanical viewpoint, this method cannot be seriously criticized, but in practice there seems sometimes to be difficulty in making the rubber sufficiently soft to protect the surge tank or distance member from appreciable torsional stress. The result, in some cases, has been the development of fine cracks in the structure of the surge tank, with consequent loss of air pressure.

To avoid any such trouble, Carrimore Six-Wheelers Ltd. have abandoned the long air bag on each side in favour of two shorter ones, so that the springs for each axle of the bogie are separate. The axles themselves are located by radius rods pivoted on brackets mounted below the chassis frame. At the same time, separate surge tanks have been avoided completely by using the air bag of one spring as the surge tank for the other. The layout does limit the designer in his choice of periodicity, but is said to result in a frequency of about 90 cycles per minute, which is generally regarded as satisfactory for this class of vehicle. It should, perhaps, be mentioned that there seems to be room for doubt as to whether this arrangement can, in fact, provide any fixed periodicity. According to one theory, the figure quoted can apply only if one axle is at rest while the other is rising or falling. If both move together, there would appear to be no surge-tank effect for either, whereas if they move simultaneously in opposite directions the result must be something akin to a surge tank of infinite capacity.

Attached to each end of each axle beam there are two longitudinal radius rods, one above the other, giving a parallel-rule action which resists braking torque reaction. Additionally, Panhard rods provide lateral location for the axles. There are thus ten links, with a total of twenty pivot bearings, a circumstance which might once have been regarded as a serious weakness, but which is scarcely





Above: The Brockhouse Mk IV interchangeable automatic coupling on a prime mover

Left: Taskers 12 ton rear-steering semi-trailer designed so that the rear wheels follow in the tracks of the front ones throughout most of the steering range

objectionable when these bearings are modern rubber bushes. The air bags of this Carrimore semi-trailer are of André manufacture, with two convolutions, and are 29 in long by 8½ in wide. With full load, the working pressure is 46 lb/in², and it drops to about one-sixth of that figure when the trailer is empty. The maximum total load carried by the two axles is 13 ton.

Reverting now to the subject of braking, an interesting feature of the Brockhouse Mk IV interchangeable semi-trailer coupling is the use of a Clayton Dewandre Hydrovac suspended vacuum servo unit for trailer brake operation. In this type of servo, both sides of the piston are exposed to a sub-atmospheric pressure when the unit is at rest. Actuation of the piston is effected by the admission of air to one side so that the resulting higher pressure on that side forces the piston towards the other end, in which the depression has not been reduced.

A practical benefit of the system is a marked reduction in the lag between the driver's initiatory action and the actual application of the brakes. In this case, the reduction is said to be from about 6 sec to approximately 1 sec. Consequently there is little time for the rear part of an articulated vehicle to attempt to over-run the tractor, and a prime cause of jack-knifing is thus eliminated. At the same time, of course, the stopping distance from any given speed is greatly reduced, without increasing the rate of deceleration.

Besides the automatic operation of the trailer brakes when the tractor brakes are applied, there is a direct manual control on the steering column to enable the driver to apply the trailer brakes independently of the tractor brakes if he wishes to do so for any reason. Further, he can lock them on before he leaves the cab. This could be important in circumstances such as a stop on an icy gradient, where the tractor handbrake alone might not hold the vehicle while the driver gets out to apply the usual form of trailer handbrake.

Another noteworthy feature of this new Brockhouse design is the coupling and uncoupling arrangement. The first of these two operations is automatic when the tractor is backed under the trailer. Dual locking hooks with powerful springs complete the engagement, and a warning light in the cab goes out only when these hooks are fully engaged. For uncoupling the trailer, there is a simple hydraulic ram, the release valve of which is in the cab. Before the trailer can be uncoupled, this valve must be closed, and then six full strokes of a double-acting hand pump are needed for the ram to disengage the hooks: this is a safety measure to prevent unintentional or mischievous release of the trailer.

All the hydraulic and vacuum equipment is installed on the tractor vehicle. The hooks for the coupling are there, of course, mounted close together midway between the ramps, and so are the Hydrovac unit and the hydraulic cylinder that it energizes to apply the trailer brakes. The action of this slave cylinder is conveyed to the trailer brake linkage by a lever mounted under the tractor fifth wheel; the end of the lever moves vertically under a short push rod which passes upward through the centre of the trailer coupling.

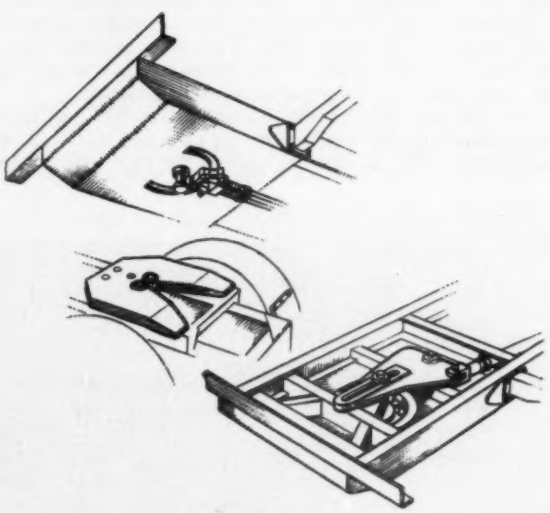
In the congested conditions of modern traffic, criticism can be aimed at any type of vehicle that needs more than its fair share of road width. It is on corners and bends that vehicle width plus a small margin is apt to be less than enough, and it is precisely at such places that any road-greediness is most reprehensible. The fault is present in minor degree on any four-wheeler because its rear wheels have a smaller turning circle than is needed by the front ones. With the average articulated vehicle trailer outfit, this effect is magnified. It is indeed probable that no normal semi-trailer can make a 90 deg turn in a 25 ft road without trespassing some way over the white line. To cure this trouble is the object of a recent design, by Taskers of Andover (1932) Ltd., which is illustrated in the sketch on the right.

The fifth-wheel coupling of the B. Dixon-Bate semi-trailer conversion of the Land-Rover is mounted on a sub-frame secured to the chassis

For many years designers have understood the geometry of self-tracking trains of trailers and such road trains have been built at various times. Small-scale examples can be seen today in regular and successful use on many railway platforms. Certain complications arise, however, when the same principles are to be applied to an articulated vehicle of the semi-trailer type.

These difficulties have been recognized and apparently solved in the Taskers 12 ton rear-steering semi-trailer. As in the road trains, the purpose is to make the rear wheels of the trailer follow the tracks of the preceding wheels, so that they do not cut corners. The main complication lies in the fact that, whereas the tractor may swing through 90 deg or more in relation to the trailer, the wheels of the latter—as in almost any vehicle—must have a restricted lock if they are not to foul some neighbouring component of the frame or chassis.

In the Taskers design for the solution of this problem, the tractor part of the fifth-wheel coupling can be of almost any normal type with a V-throat, and no extra operation is involved in coupling or uncoupling tractor and trailer. Under the trailer plate that bears on this fifth wheel, there is a sliding block tapered to match the angle of the V-throat and urged by springs towards the king pin around which articulation occurs. Cut through the trailer plate is an arcuate slot



Details of the rear wheel steering arrangement installed on the Taskers semi-trailer, which is illustrated at the foot of the opposite page

Left: B. Dixon-Bate conversion of a Land-Rover, with an articulated low loading semi-trailer. A readily detachable pick-up body is available for use when the trailer is not required and is uncoupled

Below: Model 570 Certic coupling produced by the Davies Magnet Works Ltd., of Ware, Herts. The object of this design is to improve cornering stability of the vehicle

forming considerably more than half a circle concentric with the king pin, as shown in the accompanying illustration.

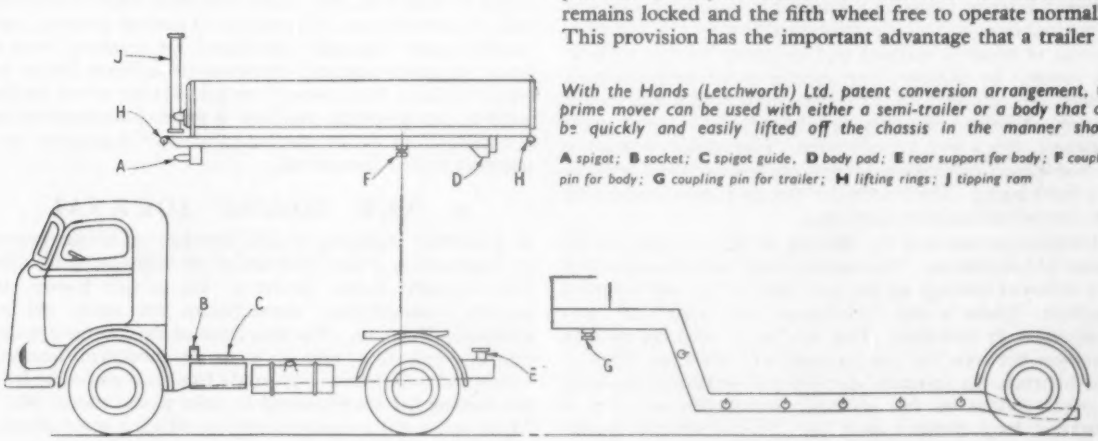
Mounted to travel in this slot is a pin that carries the V-block and which also registers in a straight slot in a bell-crank or rectangular lever pivoted in the trailer frame above the fifth-wheel plate. When the tractor turns under the trailer, the V-block is moved by the fifth wheel around the curved slot and, therefore, turns the lever on its pivot on the trailer frame. The angular displacement of this lever cannot proceed beyond the position where its straight slot is tangential to the curved slot. Further relative motion between the tractor and the trailer would ultimately move the lever back towards its straight-ahead position, but, in fact, there is in the neighbourhood of the tangential position a considerable angle of movement through which the lever remains practically stationary.

The rest of this 12 ton vehicle is straightforward enough. At the rear there are four wheels in line; each pair is mounted on its own short axle, carried in a bracket that is pivoted, by a turntable arrangement, on the trailer chassis frame. A track rod connects the two axles and a drag link extends forward from the nearside assembly to the third point of the lever above the fifth wheel. The result is that, throughout the normal range, the trailer wheels are automatically steered to track with those of the tractor. Beyond that normal range, as when manoeuvring in a confined space, the trailer wheels are still part way towards the true tracking position. Thus, although the full theoretical advantage is not obtained, there is still a considerable advantage over the orthodox layout. It is claimed that this vehicle can, in fact, make a right-angle turn within its own half of a 25 ft wide road.

In connection with fifth-wheel couplings for semi-trailers, there is another development of some technical and practical interest. This is the Model 570 Certic coupling of the Davies Magnet Works Ltd., Ware, Herts., the purpose of which is to improve the stability of an articulated vehicle when cornering. In this arrangement, the swivelling between the two units does not occur at the fifth wheel itself. The latter is retained as a convenient and familiar method of coupling the tractor to any existing semi-trailer, but there is also a swivelling undercarriage on the tractor, below the fifth wheel. Logically enough, this under carriage has been described as the sixth wheel.

Underneath the bolster plate of the semi-trailer is a tongue that, when the tractor is coupled to the trailer, locks the fifth wheel in line with the trailer. Simultaneously it unlocks the sixth wheel so that the latter is free to swivel in accordance with the relative motion between tractor and trailer. The sixth wheel, however, does not turn about the same axis as the fifth-wheel king pin. Instead, the actual swivel axis is ahead of the king pin axis. Consequently, the king pin axis moves toward the inside of the curve when the vehicle is cornering, and the vertical load, due to the trailer, therefore produces a couple opposing that arising from centrifugal force. The result is less roll on corners.

The bolster plate tongue that locks the fifth wheel can be put out of use, if desired. In that case the sixth wheel remains locked and the fifth wheel free to operate normally. This provision has the important advantage that a trailer of



With the Hands (Letchworth) Ltd. patent conversion arrangement, the prime mover can be used with either a semi-trailer or a body that can be quickly and easily lifted off the chassis in the manner shown

A *spigot*; **B** *socket*; **C** *spigot guide*, **D** *body pad*; **E** *rear support for body*; **F** *coupling pin for body*; **G** *coupling pin for trailer*; **H** *lifting rings*; **J** *tipping ram*

this type can be used conventionally with any normal fifth-wheel coupling. Similarly the sixth-wheel coupling on the tractor can be used with any conventional semi-trailer because the sixth-wheel will then be locked and the fifth wheel will function normally.

One other development deserves mention here, although it actually concerns the trailer less than the tractor vehicle. It is a semi-trailer conversion made by B. Dixon-Bate Ltd., of Chester, for the Land-Rover 88. The fifth-wheel coupling is a self-contained unit with its own sub-frame for clamping directly to the Land-Rover chassis side members. It is supplied complete with rubber mudguards, all connections and rear lamps. Not only is it easy to install, but also it is easy to remove and a similarly detachable pick-up body is available to replace it. This enables the Land-Rover to be used either as a complete vehicle or as a tractor for the semi-trailer.

A somewhat similar idea has been developed even more fully, by Hands (Letchworth) Ltd., for application to larger chassis of various makes. These can be used either as tractors for all sorts of semi-trailers or as self-contained vehicles with tipping or other bodies. In this case, the lift-off body is attached by the trailer coupling, in conjunction with other fittings which do not interfere with the semi-trailer function. Change-over from one arrangement to another would, therefore, seem to be particularly simple.

On the Dixon-Bate Land-Rover conversion, braking is effected simply by means of a connection between the Girling hydraulic brakes of the semi-trailer and the vehicle's hydraulic system. This may seem a little daring in view of the weights involved: the trailer weighs 14 cwt and can carry a maximum load of 33 cwt. Presumably, too, the operation of the additional wheel cylinders must mean that brake adjustment is necessary more frequently. However, it is understood that the scheme is satisfactory in practice and that, after all, is the ultimate consideration.

Medium Width Steel Strip

SINCE the war, the demand for rolled steel plates, sheet and strip has been increasing faster than that for other products of the steel mills. Among the reasons for this are the growth in the demand for motor vehicles, refrigerators and other manufactured goods, owing to the rising standard of living, and developments in fabrication techniques. This trend prompted The United Steel Companies Ltd., of 17 Westbourne Road, Sheffield 10, to undertake market research to determine the size of the potential demand and the maximum width of strip that would be required. At the same time, the staff of Steel, Peach and Tozer were studying the latest developments in strip mill design in Europe and the United States.

As a result of these investigations, it was decided to build a highly mechanized, continuous hot strip mill capable of rolling mild, carbon and special steels up to 18 in wide. The aim was at filling the gap between the outputs of narrow and wide strip mills already operating in this country. Thus, the Brinsworth mill was conceived and was commissioned in the autumn of 1957; it has now been run in and is operating normally. This mill will have an ultimate capacity of 8,000 ton per week, and the firm claim that it will set new standards for close tolerances and surface finish.

Among the interesting features of the new mill are the communications system and the Centralograph. Rapid dissemination of information is of course vital to the efficient operation of a modern high speed rolling mill, as it also is in many other types of factory organized for a high rate of output. In the Brinsworth mill, intercommunication between different locations is effected by means of a system of microphones and loudspeakers installed at 28 key points, any one of which is in direct and immediate contact with all the others. In addition, two smaller inter-communication systems are provided for the furnace pusher and mill record set up. General messages can be broadcast from eight positions, over a loud hailer system. This enables contact to be maintained with personnel who are not normally working at a fixed point. The loud hailer system is also linked with the intercommunication network.

Information required for the mill records is conveyed by means of teleprinters. This enables each slab to be identified and followed through all the processes to the coil weighing machine. There is also a pneumatic tube system of communication in operation. One section is used for passing messages between the slab bay and the reheating furnaces and between the furnaces and the coil weighing machine. Another section is for external communication, over a relatively long distance with the Templeborough works.

The Centralograph is a recording instrument for the centralized registration of the production performance of up to 20 machines. During normal production, detecting contacts on the machines transmit electrical impulses to the Centralograph, and these impulses are recorded as short horizontal lines on a time-referenced diagram called a Centralogram. This diagram is divided into 20 columns to represent the machines and it shows at a glance the machine time, represented by the horizontal lines, and the idle time, represented by the blank spaces.

Reasons for stoppages are recorded manually by means of a dial near each machine and are recorded on the Centralogram in the form of a numeral at the side of the line registration. Each numeral corresponds to a certain reason for stoppage, according to a predetermined code.

GERMAN STANDARDS

THE German Standards Committee, Deutscher Normenausschuss, has now established a special department to prepare translations of German industrial standards in English, Spanish and French. So far, four hundred and fifty translations have been made. Lists of the translations available are obtainable free of charge from the Beuth-Vertrieb GmbH, Berlin W 15, Uhlandstrasse 175.

MASKING TAPE

THE Permacel Tapes Division of Johnson and Johnson (Great Britain) Ltd., has added to its wide range of products, with the introduction of Permacel 93 general purpose paper masking tape. Specially developed for masking from all forms of spray painting, Permacel 93 adheres firmly but releases cleanly from painted surfaces. It has a thin backing material that keeps the build-up of paint to a minimum, and is unaffected by the recognized solvents; it is available in all standard widths from stock.

A NEW HOUSE JOURNAL

A RECENT addition to the number of house journals is *Transmission Times*, introduced by Self-Changing Gears Ltd., Lythalls Lane, Coventry. As is well known, this concern manufactures transmissions for road, rail and marine applications. The first issue of the journal appeared in mid-September, and it is to be published quarterly. Firms and individuals who would like their names added to the mailing list are requested to write to the editor, Mr. K. Montrose, at the company's address which is given above.

M.A.N. Air Suspension

German Rolling Seal Type Air Spring System Now in Production for a Bus Chassis

BECAUSE of the large variations between the empty and fully laden weights of buses and heavy lorries, air suspension probably offers greater advantages for such vehicles than for private cars. The increasing interest in suspension systems of this type is thus not surprising, and several examples have appeared at the various commercial vehicle exhibitions during the past year or two. A typical layout exhibited in prototype form at the 1957 Frankfurt show was that of the M.A.N. 760 UO1 city bus chassis.

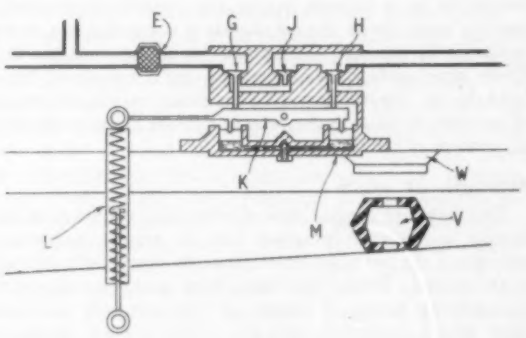
This air suspension system has now gone into production after an intensive development stage. Each wheel has its own spring, of the rolling seal type, and the front wheels are independently suspended on transverse wishbones. A beam axle is retained at the rear; as is essential with air springing, it is effectively located in both directions. Two long, trailing arms control the axle longitudinally, and there is a Panhard rod for lateral location.

The air reservoir for the suspension system is in tandem with that for the braking system, which is supplied with air at 7 atmospheres pressure by a belt driven two-cylinder compressor. Between the two reservoirs is an overflow valve that reduces the pressure to 5·3 atmospheres for the suspension reservoir. From the latter, pipes lead through air filters to the four levelling valves, and thence to the air springs.

In each levelling valve are three poppet valves: an inlet valve, an outlet valve exhausting to atmosphere, and a non-return valve between the other two. Actuating the inlet or exhaust valve, according to the circumstances, is a rocking beam, connected by a telescopic, spring link to the wishbone or trailing arm. This link, together with a hydraulic damper, or delay device, incorporated in the levelling valve, prevents operation of the valve in response to transient deflections of the road wheels. The damper is an oil dashpot and has two pistons, connected one to each end of the rocking beam. In the air springs, the maximum working pressure is 5 atmospheres, but should suspension movement cause it to exceed the reservoir pressure, the non-return valve prevents transmission of the excess pressure back to the reservoir.

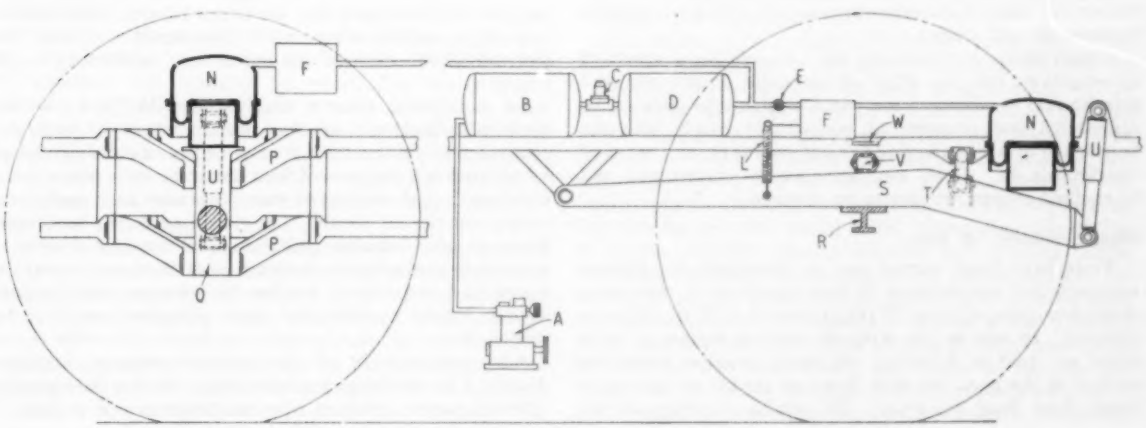
The outer, stationary portion of each of the four spring units is attached rigidly to the underfloor structure of the vehicle. This portion comprises two parts, the dome and the skirt; both have a horizontal flange and between these flanges is sandwiched the periphery of the annular rubber and cord diaphragm that forms the rolling seal. The inner edge of the diaphragm is clamped to the top of the cylindrical moving portion of the spring.

As already indicated, suspension of the front wheels is independent. At each side are two trapezoidal wishbone members, pivoted one above the other in the usual way and linked by a vertical member carrying the stub axle assembly. The moving portion of the air spring is mounted on a platform on top of the vertical member. Whereas the wishbones have forged arms, the two trailing arms for the rear axle are built up from pressings. Each pivots on a bonded rubber bearing, and the pivot points are well ahead of the axle. Behind this, the arms are downswept, and brackets at their rearward ends support the moving portions of the air springs, which are mounted in the rear of the wheel arches.



Below is shown the layout of the M.A.N. bus air suspension. On the right is a sectional view of one of the four levelling valves

A *air compressor;* **B** *brake reservoir;* **C** *overflow valve;* **D** *suspension reservoir;* **E** *air filter;* **F** *levelling valves;* **G** *inlet valve;* **H** *outlet valve;* **J** *non-return valve;* **K** *rocking beam;* **L** *spring link;* **M** *levelling valve damper;* **N** *air springs;* **P** *wishbones;* **Q** *vertical member;* **R** *rear axle beam;* **S** *trailing arm;* **T** *Panhard rod;* **U** *suspension dampers;* **V** *rubber buffer;* **W** *contact pad*



Hydraulic dampers control the action of the springs. The forward dampers are fitted between the chassis structure and the lower end of the vertical member linking the wishbones, while the rear units are situated immediately to the rear of the springs. At each end of the tubular Panhard rod is an eye housing a bonded rubber pivot bush; one end of the rod is connected to the chassis and the other to the left-hand trailing arm, at a point a short distance behind the axle beam. To form a bump stop for the axle and to cater for the possible but unlikely event of a serious reduction in air pressure, a rubber buffer is fitted to each arm, and there are contact pads for these buffers on the chassis.

The manufacturers claim that the diaphragms of the air springs should have a life exceeding 60,000 miles, and that they can readily be replaced. By suitable design of the diaphragm and the fixed and moving portions of the springs, suitable load deflection characteristics have been obtained, and the natural frequencies of the suspension are said to be satisfactorily low. In respect of the riding qualities of the bus, the expectations of the designers have been exceeded.

Recent Reports of the M.E.R.L.

A BRANCH of the Department of Scientific and Industrial Research, the Mechanical Engineering Research Laboratory, has been established at East Kilbride, Glasgow. It has a wide range of interests, including fatigue and creep, bearings, lubrication and wear, performance of gears and other mechanisms, heat transfer and applied thermodynamics, and metalworking processes generally. To assist interested firms, the laboratory issues from time to time summaries of its activities; the first five of these summaries have recently been published.

Air content of oils

If air is dissolved in hydraulic oil, it can give rise to loss of efficiency in pumps, delayed build-up of pressure in presses and instability in servo mechanisms. For its investigations into these effects, the laboratory has developed a simple apparatus for measuring the air content of oil samples.

A steel cylinder contains a cage carrying steel balls, and to the bottom of the cylinder is screwed a steel sample bottle, which takes a standard volume of oil. The sample bottle is isolated from the cylinder by a weighted valve. After evacuation by a vacuum pump, the cylinder is inverted so that the valve opens; the oil sample is subjected to a sudden reduction in pressure and spreads as a film over the balls. Their large surface area helps the rapid release of the air from the oil. An ordinary vacuum gauge records the increase of pressure in the cylinder, which increase is a measure of the air content of the oil.

Strength of joints

The fork and tongue type of pin-joint, common in automobile and aircraft practice, can be greatly increased in strength if the pin is an interference fit instead of a sliding fit in the tongue. Fatigue tests have been carried out on joints of this pattern having a tongue of high-strength aluminium alloy and a hardened steel pin. The original design was found to have a much lower fatigue strength than the theoretical value, apparently because of fretting corrosion between pin and tongue.

Considerable improvement was obtained as a result of investigations into the effect of variations in pin size and interference fit. Since some joints of this type have to be dismantled and reassembled periodically, study has also been made of designs having a pin of sliding fit in a bush of interference fit. Here, too, attention to dimensions and fit enabled greater strength to be obtained.

Measurement of flow

Tests have been carried out to determine the relative accuracy and convenience of four methods of measuring water flow rates of up to 27,000 g.p.m. in a 40 in diameter pipeline. In two of the methods, current meters or pitot tubes are used to determine the local velocities across the section of the pipe; the bulk flow can readily be calculated from these local velocities. By careful selection of the measurement points, it has been possible to reduce their number without loss of accuracy. Current meters are small propellers that revolve at a speed proportional to the local velocity. By the use of electronic equipment, the revolutions of up to twenty-one meters in a given time can be recorded automatically.

To obtain the flow directly, the salt-velocity and salt-dilution methods are employed. In the first of these, a quantity of salt solution, of higher electrical conductivity than that of the water, is suddenly injected into the pipeline. Its passage is timed between two downstream positions a known distance apart. Improved injection gear and detection electrodes have been developed by the laboratory. In the salt-dilution method, a solution of known strength is pumped continuously at a steady rate into the pipe. Samples are taken at a downstream position, and their concentration is compared with that at the injection point.

The current meter system was used as a reference to determine the standard of accuracy of the other methods. Most of the results obtained were found to be within ± 2 per cent of the current meter values.

Heat transfer

A new M.E.R.L. publication, *Heat Bibliography* 1955-56, contains no fewer than 12,000 references to published papers and books on all aspects of heat transfer and related subjects. There are references to heat transfer by conduction, convection and radiation; boiling, condensation and evaporation; heat exchangers of various kinds; and physical properties such as entropy, specific heats, thermal conductivity and viscosity, all of which are dealt with in some detail.

Hydraulic relief valves

The requirements of a relief valve are that it should open at a predetermined pressure, as quickly as possible without imposing shock loads on the circuit, and that it should not oscillate or cause noise while open. Tests on eight commercial valves revealed that the circuit in which the valve is used has a marked effect on its characteristics. Under the test conditions, none of the valves was satisfactory in all respects.

An interesting scheme tried at the M.E.R.L. is the electrical simulation of the characteristics of hydraulic components. For example, a valve orifice can be regarded as a resistance and the mass of fluid above the valve piston as an inductance. Calculations on these lines have been made for a simple but typical circuit. The circuit equations have been found to give valuable guidance as to whether a valve is adequately damped and whether it gives the correct stroke for a particular rate of flow. Further development of the method should enable considerably more complex circuits to be investigated.

Additional details of the various research activities described in the foregoing, and copies of *Heat Bibliography* 1955-56, can be obtained from the laboratory on request.

Bus Maintenance Methods

London Transport Secures Economies by Reliance on Frequent Inspections Instead of Major Docking

CONSIDERABLE economies are expected from new maintenance methods recently adopted by London Transport for its buses. These have been made possible by the reliability and efficiency of the modern London bus and its components, and also by increased mechanization in the garages, and by staff co-operation. The main effect is a reduction in the number of staff required for maintenance work. This has been done by abolishing the periodic full day check in dock.

The new maintenance system is based on a thorough external examination every three weeks, so there are eighteen inspections per 54-week cycle. As little dismantling as possible is done. Engines are changed only when loss of power or other defects become apparent, and batteries are changed only when they are becoming defective. Very few items are changed purely on a time, mileage, or age basis. The three-weekly inspection is carried out while the bus is in the garage between morning and evening peak periods and therefore the vehicle is available when most required for operation on that day.

Formerly, London Transport buses were given a full day major check every twenty-seven weeks, and this entailed the transfer of vehicles from subsidiary garages to parent garages. During this major check, certain components were replaced on a time or mileage basis. Under the new system, however, these parts are changed, in general, only when they actually need replacement. It is now seldom necessary to send vehicles to parent garages, so the out-of-service mileage of the vehicles is greatly reduced.

Apart from the daily tasks of checking engine oil and cooling water, re-fuelling, interior cleaning and exterior washing as required—all of which are still carried out as before—the former maintenance methods were based on three rotas. The A rota, every three weeks, included the topping up of batteries, lubrication where necessary, vacuum cleaning of cushions, and general inspection for faults. Every nine weeks additional tasks were undertaken, on B rota, and every twenty-seven weeks the buses were given a major check in dock, on the C rota.

It was found that increasing reliability of units permitted gradual extensions of the overhaul period. For example, it was the practice at major checks in dock to remove the fuel injection pump in order to verify calibration. Late in 1957, however, the period between removals was extended to fifty-four weeks. Injectors on the other hand are removed for overhaul and replaced by overhauled spares every twenty-seven weeks, although a number of injectors have been run for twelve months without ill-effects. A general adoption of this longer period, which is under consideration, would mean that injectors would no longer be serviced at the garage but would be overhauled to high standards maintained at the factory.

It was customary for brake drums and shoes to be removed at every major dock, that is, every twenty-seven weeks, and linings were renewed if it was not certain that they would last until the next major dock. In practice, this meant that linings were nearly always changed at major docks. The new practice is to examine linings during the three-weekly inspection, and when it is found that their thickness has been reduced to not more than $\frac{1}{4}$ in, they are scheduled for replacement within a fortnight. This change in system has reduced the consumption of linings by half.

The 9·6 litre engines, which are derated from 125 b.h.p. to 115 b.h.p., are very reliable and, on average, need changing only every three years; indeed, many of them run for more than four years. Cylinder heads are removed only when necessary, and often not at all between engine overhauls. Engine sumps are never removed at the garages.

Steering boxes will easily function up to four years, from overhaul to overhaul, without attention except lubrication, and the gearbox and fluid flywheel will run for more than three years without attention other than the addition of oil. The front axle will not run for as long; however, this assembly is called upon to conform to particularly high standards and possibly those standards might be relaxed without any prejudice to safety. This would enable the period between front axle overhauls to be increased.

When the vehicles are overhauled, which is approximately every $3\frac{1}{2}$ years, at Aldenham Works, most of the units removed to give access for thorough chassis inspection are refitted without attention. These include the engine; fluid flywheel; gearbox; front axle, provided it is within certain wear limits; starter; dynamo and differential.

The vehicle overhaul period of $3\frac{1}{2}$ years set at present by London Transport is almost entirely based on body requirements. Improvements in paint life and finish may make it possible to extend this period a little in due course.

Advances in respect of both reliability and design, such as those already mentioned, have permitted the adoption of a new approach to maintenance procedure and have provided the basis of the revised system of three-weekly inspections, eliminating the need for the twenty-seven week major dock. During the three-weekly inspection, those tasks requiring attention at longer intervals—nine, eighteen, twenty-seven and fifty-four weeks—are superimposed on the basic work, in accordance with a programme designed to obtain a convenient spread of work. At each three-weekly inspection, a comprehensive external examination of mechanical, electrical, and body components is made. All defects are remedied or noted for attention as soon as practicable. The vehicle is washed externally and the seat cushions are vacuum cleaned. Any necessary lubrication or topping up is also carried out.

The engine oil is changed every nine weeks, and at the same time the air pressure system is thoroughly checked and more extensive cleaning of the body is undertaken. Every eighteen weeks the interior of the body is thoroughly cleaned. Extra tasks which are superimposed at twenty-seven week intervals include replacing the injectors, checking and adjusting tappets and oil feed to rockers, changing fuel filter elements, checking and rectifying tracking, topping up the steering box and wheel hubs, replenishing handbrake oil baths, checking dynamo brushes and focusing lamps, removing, checking and refitting starter motors and also the battery, if required, and certain painting and staining work of a minor nature. The chassis is cleaned at twenty-seven week intervals, although it may be possible to extend this to intervals of fifty-four weeks. In terms of mileage the three-week frequency of inspection corresponds roughly to 2,400 miles, so something over 40,000 miles is completed

by a bus in a fifty-four week cycle. The actual mileage varies slightly with the duties performed by any particular bus.

It was the former practice at the major checks regularly to remove gearbox lids, check adjustment, and so on. This has now been discontinued, as also has the practice of removing brake drums and other components at twenty-seven week intervals, as already mentioned. At one time, brake cylinders and front hubs were removed at each major check, regreased, and adjusted, but this has also been discontinued in the light of performance experience.

London Transport has in fact been moving towards these new maintenance principles for some time, so the change is not in itself revolutionary, although acceptance of the principle of abolishing the full day major dock is, and it is this change of procedure which has opened the way to the economies mentioned previously. Agreement has been reached, between London Transport and representatives of the staff, on a reduction in the proportion of maintenance staff per bus, based on improved equipment and increased effort. The results of the savings are shared between London Transport and the staff, through added payments under incentive bonus schemes. A reduction in the number of administrative and supervisory staff covering maintenance is also being secured by re-organization. Some hundreds of staff will be saved by these measures. The reduction in staff is already catered for by recent agreements providing for the retirement of over-age staff and for voluntary retirement by staff approaching retirement age.

A further contribution towards easier maintenance is being made by increased mechanization at garages, including mechanical washing plants, large vacuum cleaning plants for saloon cleaning when the buses return to the garage, and steam and hot-water cleaning equipment. The number of bus washing machines is now being increased to equip all major garages. Washing by machine, with detergents, can take the place of the external soap wash formerly undertaken at major docks. This reduces the time taken to one hour as against the whole shift taken by one man washing by hand. The new maintenance methods have been devised by Mr. K. G. Shave, Rolling Stock Engineer (Road Services), and his staff, to the requirements of Mr. A. A. M. Durrant, Chief Mechanical Engineer (Road Services), London Transport Executive, 55, Broadway, London, S.W.1.

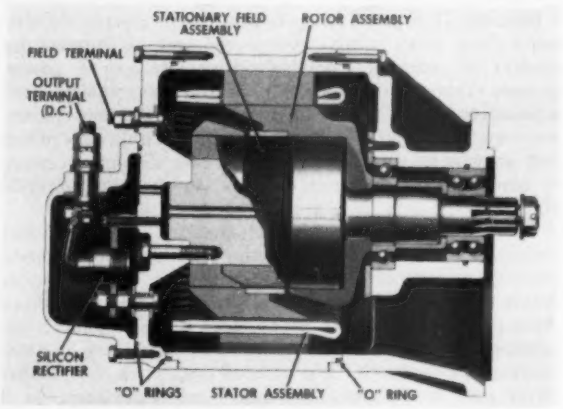
D.C. Generator

American Designed, Oil-Cooled Unit Without Brushes or Commutators

THE Truck and Coach Division of General Motors Corp. has introduced a novel generator intended primarily to cater for the heavy load requirements of modern diesel buses. This generator represents a big advance in design. At normal cruising speeds, it develops 250 amp, and at idling speeds its output is 135 amp. The equipment is completely sealed for life and therefore cannot sustain damage from dust or detergents and other chemicals used for engine cleaning. All electrical windings are stationary, and there are neither brushes nor commutators. Conversion to D.C. is accomplished by a bridge of six selenium rectifiers which, by allowing the current to flow in one direction only, obviate the need for a cut-out relay.

Generously proportioned ball bearings support the rotor drive shaft, and they are the only points of contact between moving and stationary components. All mating structural parts of the housing are sealed with special temperature-resistant circular section rings. Servicing is eliminated altogether, by virtue of the absence of brushes, slip rings, rubber seals and air filters, as well as by self-lubrication and cooling by the pressure oil supply from the engine. This oil returns by gravity to the crankcase.

For use with this generator, a new transistor type voltage regulator has been designed. It has no moving parts and no mechanical features such as bimetal strips, calibrated springs, contact-points or air gaps. A noteworthy feature is that it is unaffected by temperature changes, humidity or vibration. The generator voltage is controlled and is regulated by a single setting which can be made with a screwdriver.



The new D.C. generator developed by General Motors Corporation

Blackheart Malleable Iron Castings

THREE grades of blackheart malleable iron castings, B18/6, B20/10 and B22/14, form the subject of the latest revision of the British Standard B.S. 310 : 1958. The chemical composition of the metal of the castings is considered to be of less importance than the mechanical properties. In consequence, compliance with the requirements of the specified tests is to be regarded as the main criterion of the material's suitability for the purpose for which it is required.

The provision and heat treatment of the test bars are specified, as are tensile test and bend test and hardness requirements; provision is also made for additional tests to be undertaken by arrangement with the manufacturer. Alternative dimensions, based on practice in several other countries, are given. They have been included in order to gain experience with them in the United Kingdom, and to facilitate the exchange of information with other countries. Copies of this Standard can be obtained from the British Standards Institution, Sales Branch, 2 Park Street, London, W.1. The price is 4s, and postage will be charged extra.

VAUXHALL BODY PRODUCTION

A Comprehensively Planned Layout, Linking the Press Shop with the Final Assembly Shop, Under a Single Roof

INCLUDING a pressed panel store, of 106,000 ft², and a section for the production of welded sub-assemblies, of 24,300 ft², the total area in the new Vauxhall building occupied in body building activities is 353,400 ft². Movement of components and sub-assemblies to feed the main body welding and the body finishing lines is by six overhead monorail conveyors having a combined total length of 5,500 ft. Two feed the right and left side frame assembly conveyors, the two side frame conveyors operate in conjunction with the body welding line, and two further conveyors bring door sub-assemblies, fabricated in the press shop, from a basement store to the door finishing line.

The two main conveyors are of the floor chain and peg type; welding and finishing systems are 828 ft and 2,461 ft in length respectively. Conveyor speeds are regulated from a central, electronically operated, control system, in terms of "number of bodies per hour." All are keyed to the main welding conveyor and some are closely synchronized. A stoppage at any point, whether caused by operation of emergency switches, drive defects, jamming, or over-runs, can immediately be located by a system of coloured lights on the control panel.

Welding Components

In an area conveniently adjacent to the ends of the side frame feeder lines and the main welding line, a wide range of structural elements, cross members, braces, brackets, and small components are welded up into sub-assemblies by a variety of methods. There are short lines for cross members, for the floor rear end panels, and two for the floor main panels—for Velox and Cresta models and for Victor saloon and estate models respectively.

On the main floor panel, for example, a British Clearing press welds in the seat braces. Between presses, the angled side flanges of the braces are spot welded, and the second press completes the number of spots required on the braces and also welds in the side sill reinforcements. The front arched side members are jigged in position and welded and next the front cross member is jigged and welded. Panels are then stacked on trucks for transfer to the main welding line. Floor rear end panels are of two types, for Velox and Cresta cars and for Victor models. These components are jigged and welded on British Clearing press welders and the spare wheel wells, horizontal and vertical pattern respectively, are spot welded in position. The assemblies are then transported to the loading position alongside the main welding line.

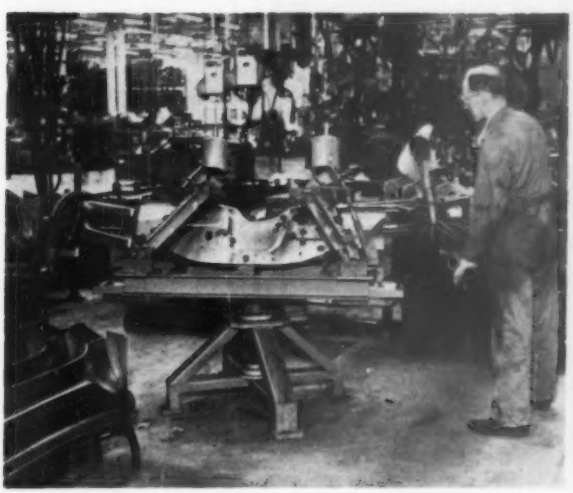
Many special jigging fixtures are provided for welding up sub-assemblies and typical examples are illustrated. Great care is taken to ensure the consistency of the component assemblies. Inspection and checking fixtures located alongside production lines are a feature of the system. The Vauxhall method of body building, understood to be unique in Britain, involves the assembly of three jigged major assemblies, the floor or underbody and two full side frames. Uniformity in the constituent parts of each of these assemblies is essential for the smooth operation of the system. There is neither time nor facility for adjustment or manhandling of structural members.

Press welding

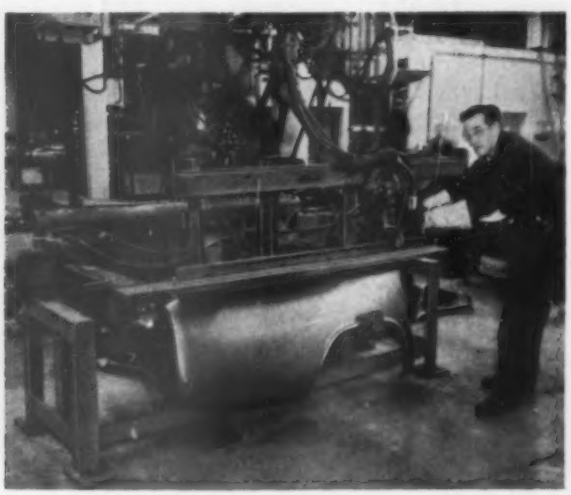
For the sub-assembly of body components by the multi-spot welding of pressings and panels, welding presses are widely employed. These machines are operated individually and also, for sequence operations, in lines interconnected by portable belt conveyors. Illustrated is such a line of five open-face presses set up for the assembly of body centre pillars.

Press-weld fixtures, designed by North West Machine Design Co. Ltd., of Kenton, Middlesex, are self-contained units. The upper portion contains hydraulically operated welding guns, welding transformers, manifolds for the

Turntable fixture for welding up the front shroud and dash sub-assembly

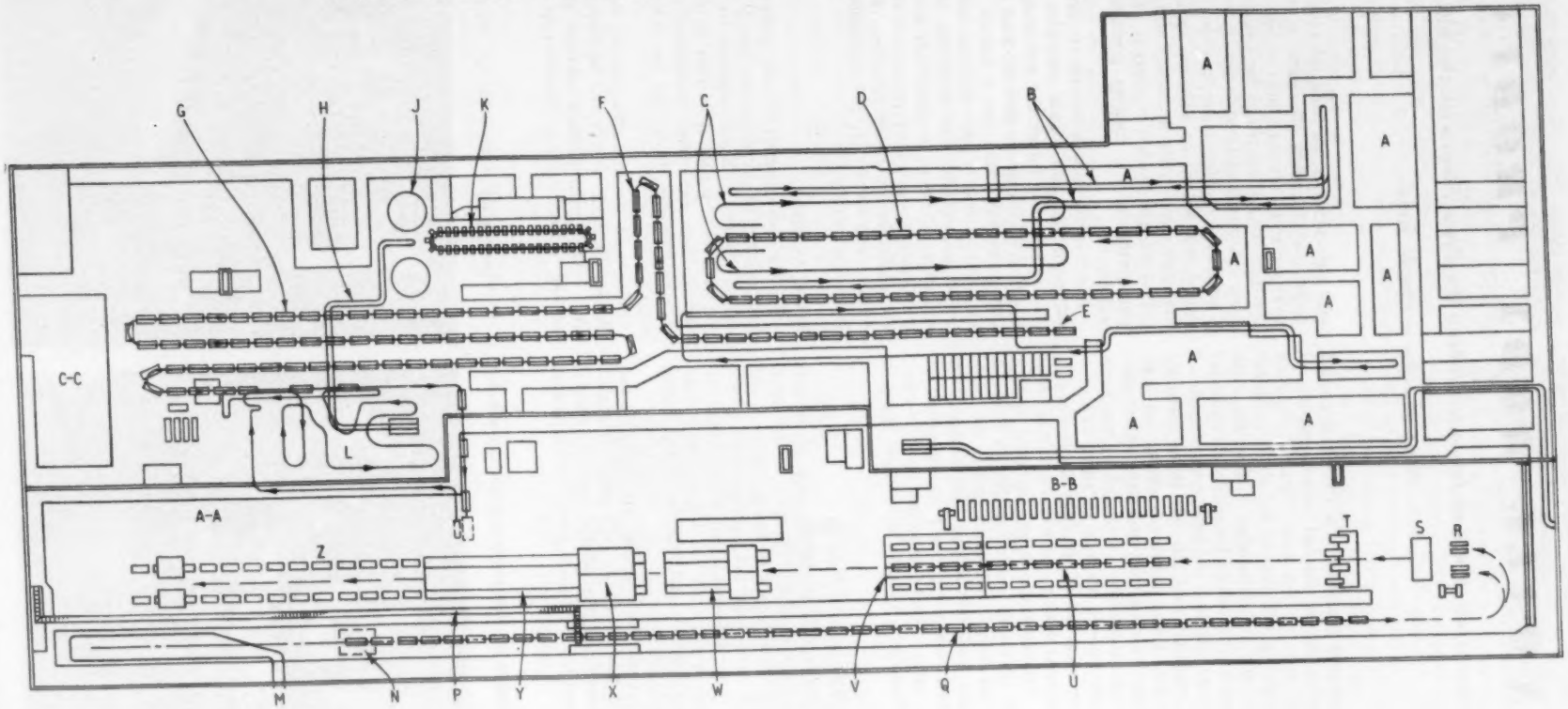


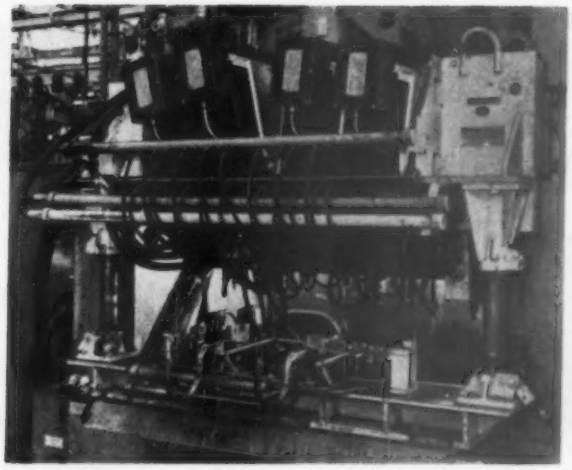
Rear quarters are welded on this jig. The gun runs on guide rails



LAYOUT OF BODY SHOP AND FINAL ASSEMBLY HALL

A *sub-assembly welding sections*; **B** *side frame feeder monorails*; **C** *side frame assembly lines*; **D** *main body welding conveyor*; **E** *solder filling line*; **F** *solder dressing tunnel*; **G** *body finishing line*; **H** *door panel and sub-assemblies from basement store*; **J** *door assembly roundabouts*; **K** *door assembly line*; **L** *body shell inspection and storage loop*; **M** *engines and axles from machine shop*; **N** *body drop*; **P** *wheel and tyre conveyor*; **Q** *final assembly line*; **R** *toe-in check*; **S** *headlamp beam setting*; **T** *roller test bays*; **U** *mechanical rectification lines and pits*; **V** *light tunnels*; **W** *mask-up for retouching*; **X** *spray booths for touch-up*; **Y** *drying ovens*; **Z** *polish and final inspection*; **A-A** *holding area*; **B-B** *rectification bays*; **C-C** *petrol tanks*





Press-weld fixture for third stage of the body centre pillar assembly, in open position

supply of cooling water to transformer secondaries and to electrode tips, and manifolds carrying pressure oil to the hydraulically operated welding guns. The lower unit locates the component in position and contains cadmium copper electrodes to act both as backing to the guns and conductors for the welding current. These electrodes are also water-cooled. Where necessary, automatic loading and ejection of the work by mechanical or pneumatic means is included, with manifolds for air being added in the latter case.

Series, direct and indirect welding can be used in the press-weld process, with series welding being the most common since it is capable of welding panels up to two thicknesses of 18 B.G. (0·049 in). Where spots are positioned closely, insulating material is placed between the guns to prevent shorting, and pincer guns are often used to overcome the complexities of space and component shape. Two main cylinder sizes are used to operate the welding guns, and the hydraulic system can be regulated from 150 to 350 lb/in² to suit the welding pressure required. Transformers are of American design with a 30 KVA current rating on a 50 per cent cycle. Five of these may be fired simultaneously from one ignition contactor.

A feature of this process is the change-over time of fixtures on the presses. A complete line of five presses can be changed over in approximately three hours, with simple coupling of oil, air and water to the mains. Fixtures are removed as a unit and transported by lift truck to an open storage and service area adjacent. There all necessary maintenance work is carried out between runs. The unit is mounted in a checking fixture, electrodes are dressed, clearances adjusted and checked, and functions tested under facsimile conditions. It is then set down, ready for immediate issue when required for a subsequent run.

Side frame assembly

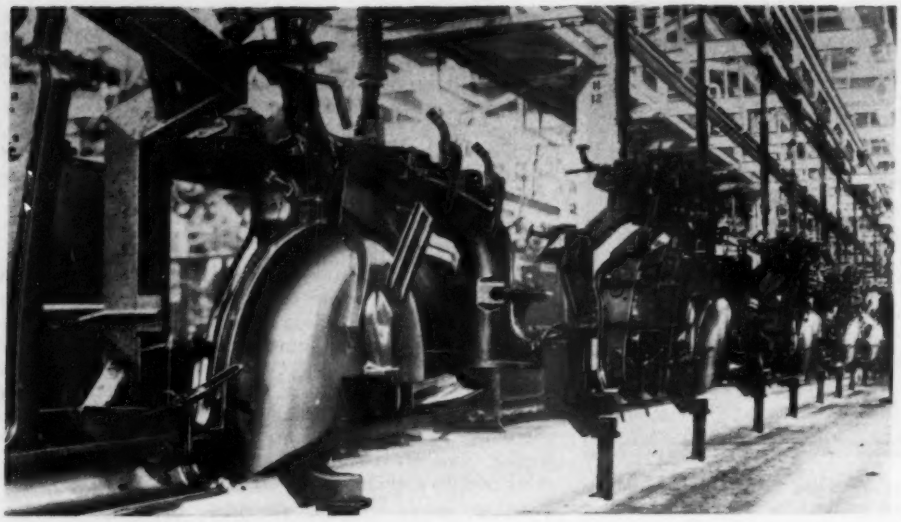
Two side frame assembly monorail conveyors, right hand and left hand, run parallel to and equally spaced from one run of the main body welding conveyor. They are served by monorail feeder conveyors bringing component items from the sub-assembly welding area. On the two conveyors there are thirty pairs of jigging fixtures. Since each is about 9 ft long and 3 ft 6 in high, a considerable problem was presented in obtaining the requisite rigidity without incurring excessive weight. The design adopted, after some intensive development, weighs approximately 870 lb.

A side frame assembly comprises five sub-assemblies; rear quarter, centre pillar, rocker panel (door sills), front hinge pillar, and roof side rail. The jigging fixtures establish important dimensions of the body shell and co-ordinate all door apertures. On the lower run of the fixture are two vertical location posts which are received in the mounting clamps on the body welding jig trucks. The transfer and locking of the loaded fixtures to the jig truck is effected manually over a pair of switch rails in the overhead conveyors. When unlocked and detached from the jig truck, the fixtures are returned through respective right and left lines of welding stations, at which further complete side frame assemblies are produced ready for loading on to a body jig truck.

Main body assembly

The body welding conveyor, of the floor chain type, is laid out in a rectangle having sides about 350 ft long and sharply radiused corners. On this are 42 jig trucks each consisting of a platform 13 ft long by 5 ft wide with two fixed wheels at the front end and a swivelling castor wheel at the rear. On the platform are mounted two precision location units, for the main floor sub-assembly and the floor rear end. The tolerance on the locating points and the component back-ups is 0·002 in and the platform itself is planned all over to a tolerance of 0·010 in. Assembly locations are thus held interchangeable between all the 42 trucks. Both Velox and Cresta floors and Victor floors are

Press welder line for the sequential assembly of body structure components



Jigging fixtures for right-hand side frame on assembly conveyor synchronized with main body floor chain conveyor

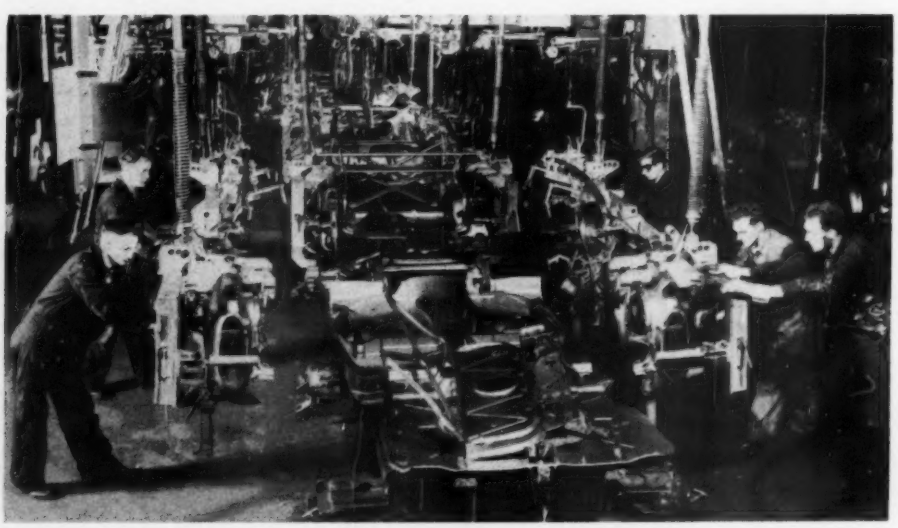
accommodated in the same fixtures, separate location points being provided for the two types. On each side of the jig trucks are two large foot-operated clamps which receive the posts of the side frame assembly fixtures. These also are precision fittings as they establish the location of the side frame assemblies relative to the structure underbody, which is formed of the two floor panels.

The load-unload station is positioned adjacent to the ends of the side frame assembly conveyors and commencement of the body finishing conveyor. The vacated jig truck thus traverses one end loop of the main conveyor before it reaches the station where the side frame fixtures are locked on. During this progress the front and rear floor panel assemblies are bolted down rigidly to their locations on the jig truck; the sequential loading of trucks being in accordance with the assembly schedule. Additionally, a number of sub-assemblies including the front shroud and dash, the rear shelf and seat squab support, are laid on the truck ready for subsequent welding into the structure.

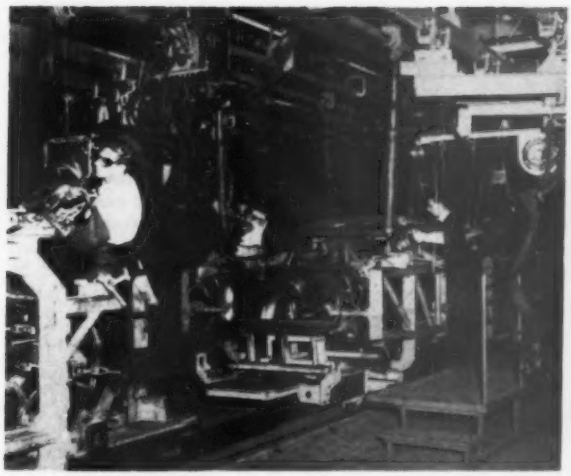
The rear panel and the front arms are spot welded, shock absorber bracket anchorages are welded to the junction flange of the front and rear panels on Victor models, and bump-stop brackets are welded on Velox and Cresta models. Seat brackets are jigged and gas-welded on Victor and Cresta models and accelerator and brake linkage brackets to all models. This completes the underbody, which is then ready to receive the side frames transferred from their respective assembly conveyors. When these are secured in position on the jig truck three tie-bars are fitted to brace the fixture assembly.

At welding stations along the line the sequence of operations is, briefly, as follows:—

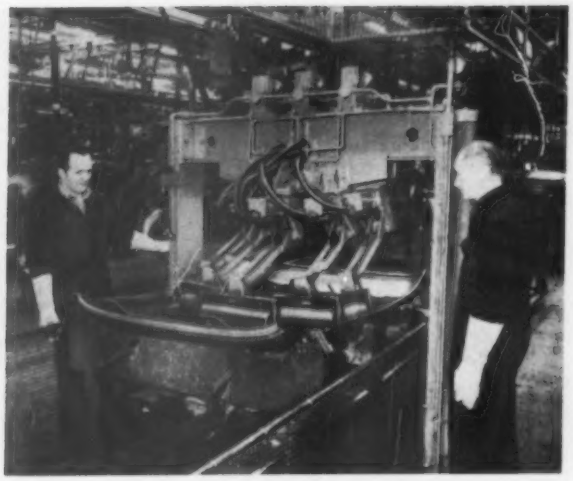
1. Front shroud and dash is jigged.
2. Shroud and sills are tacked in position.
3. Shroud, tunnel and front arms are spot-welded to the underbody.
4. Boxing panels on front arms are spot-welded.
5. Rear-end panel below boot aperture is spot-welded.
6. At a pit station, the sills and the wheel arches are spot-welded to the underbody.
7. The rear shelf and the squab support are jigged and welded to the rear quarters, and also the braces to the wheel arches.
8. The front header bar is spot-welded in. This completes the windscreen aperture, and final operations are by gas welding.
9. The rear header bar is jigged and welded in. This is virtually a repeat of the previous operation.



Transferring side frame assemblies on switch lines to the jig truck at the "lock-on" station on the main body conveyor



Welding on the roof panel at a raised platform station



"Deadener" sheet is applied to the roof panel by pressure rolls

10. The outer closures of the front ends of the shroud assembly and of the front arms are gas welded.

11. Roof panel is loaded and jigged in position at an elevated platform station. (The panel is lined with a "deadener" sheet to prevent resonance. This is secured by Bostik adhesive and is rolled on to the panel in a specially designed machine.)

12. Roof panel is spot welded to header bars.

This completes the body shell, and the side frame fixtures are then unclamped and transferred back to the sub-assembly conveyors on a second pair of switch lines.

On the return run of the main conveyor a series of smaller operations are performed; attaching the instrument panel, the front body pillar reinforcements and other minor braces, brackets and components. The body shell is then unbolted from the location mountings and is hoisted off and transferred to the storage bank at the commencement of the finishing line alongside. The jig truck is ready for reloading and continues around the line.

Door assembly and finishing

As was described in an earlier issue*, some press-welding of doors and luggage trunk lids is carried out in the press shop. A bank of these partly completed components is held in a basement store which has capacity for 30,000 assemblies in stackable pallets, and from there they are transported to the body shop on a monorail conveyor having a circuit length of 728 ft. Doors are finally assembled on two production roundabouts, each 12 ft in diameter and carrying eight welding fixtures. These units rotate at a speed synchronized with that of a 255 ft floor chain conveyor carrying 42 trucks in a continuous rectangular circuit. Each truck is equipped with an adjustable, pedestal type fixture and on these minor finishing operations—welding, brazing, and polishing—are carried out. Eight different doors are produced; front and rear, right and left, in two types for Velox and Cresta models and for Victor models.

Metal finishing conveyor

Complete body shells are carried through the body finishing stations on lightweight trucks by a pegged floor chain having a total run of 2,641 ft. Early operations are concerned with the dressing and solder-filling of welded joints. High spots on panel junctions are dressed down, gas welds are ground off by pneumatic tools, welding scale is cleaned off by electrically driven wire brushes. These brushes, also used for cleaning panels preparatory to tinning, are fed from carriages running on continuous overhead bus-bars arranged on both sides of the line.

Entocene solder paint, continuously stirred, is applied by brush to the cleaned joints, heated by gas torch to run, and wiped off. A 15 per cent tin solder is used for filling. For certain locations this is held at 375 deg F in electric solder pots and poured on the joint from a small ladle. In others, particularly on near-vertical surfaces, stick solder is heated to a plastic condition by a gas torch, and manipulated on to the joint. Then, still using the torch to maintain plasticity, the solder is worked down and smoothed off to contour by wooden formers, dressing sticks, and oiled felt wipers. There are nine fillings on each side of a Viçtor body, and eleven on each side of Velox and Cresta bodies.

On the body finishing line the first section is allocated to solder-filling operations

*"Vauxhall Motors' New Press Shop", Automobile Engineer, July, 1958.

Workers dressing solder-filled joints in an air-conditioned booth wear R.F.D. pressure hoods

After filling, the shell traverses a Spenstead looped, tunnel type booth equipped with dust-extraction and air-replacement plant giving a rapid rate of air change. Channels of running water in the floor on each side of the track carry away heavy deposited dust. Here the solder fillings are dry sanded, using Hi-cycle tools with 50-grit discs and drums of various sizes. This is followed by a second discing to smooth off and finally a sheet rub down.

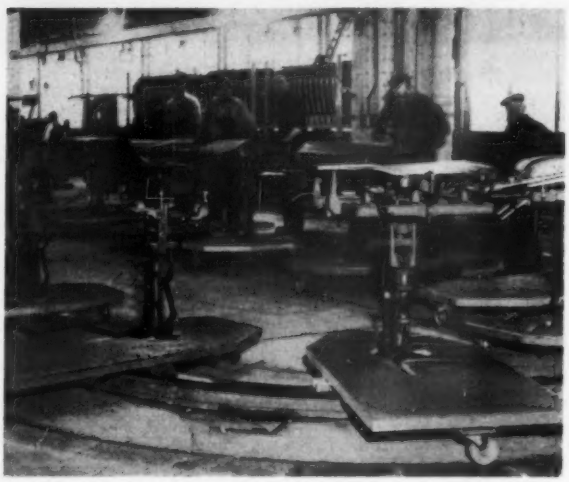
As a complete safeguard against the hazards to health of lead dust, workers in this booth wear R.F.D. pressure hoods encasing the head. Filtered air is supplied by way of a flexible conduit from the shop air line at a pressure approximately 5 lb/in² above that of atmosphere. In the open shop, workers grinding or discing steel elements are provided with pad type breathing masks and transparent face shields.

After the body shell leaves the booth, spot-welds on flanges are dressed down with 36-grit wheels and flange edges are equalized. Any deflection or waviness of a flange is removed by means of Chicago Pneumatic jaw-type pressing tools in counter-balanced ring-swivel suspension mountings on each side of the track.

Finished and inspected doors fitted with hinges, brought to the line in trolleys, are lightly affixed in position on the body shell. The luggage trunk is prepared for the lid by the fitting of hinges and the supporting torsion bar. The doors and the trunk lid are then finally hung and adjusted for closure. Minor drilling operations are performed with hand tools for such items as metal trim fittings. Solder-filled joints are hand finished with files and abrasive sheets. The body shell is then inspected for panel faults. It is chalked for low or high spots, for dents, scratches or abrasions and panel rectification is effected immediately by hand tools.

In difficult locations, external dents or other faults are filled with puddled solder. From raised platforms two inspectors check the roof panels and chalk where attention is required. This, again, receives immediate rectification where necessary. The shell is then finished off, clearing all chalkings. The sides of the roof panels are dressed with a 60-grit disc, followed by sheet emery. On the panels, draw strains or other markings are cleared by a 60-grit discing over the affected area. Incidentally, no power tool is used on solder fillings at this stage of finishing. Buffing is by dressed felt mops, removing all file marks and scratches, and cleaning over the entire exterior surface.

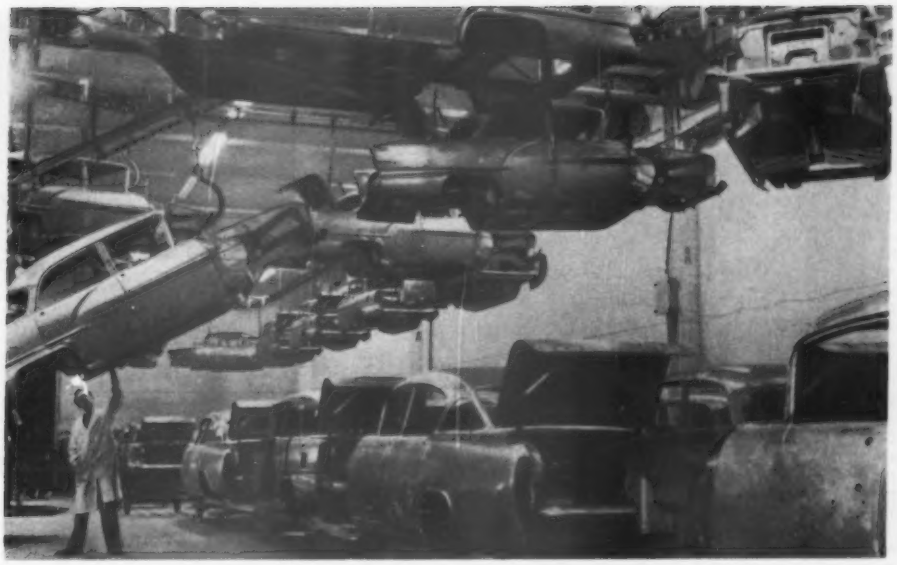
After the drip-channel extensions to the front pillars have been affixed by hollow rivets, the body shell is given a final inspection. Any minor defect discovered is immediately rectified, but in the event of more serious defects the shell is lifted off the track and replaced by a previously inspected and acceptable shell drawn from the buffer track alongside. After passing through a blow-off booth the shell is transferred to the body phosphating conveyor. This is an overhead mono-rail which can be switched to a roof-level looped



Minor welding and finishing operations on doors are carried out on this 42-truck looped conveyor

One of the two 12 ft diameter roundabouts for the welding of door assemblies

An overhead storage conveyor is used to hold out, during the mid-shift meal break, bodies "in the white" on their way to the phosphating plant



track serving as a holding bank. The capacity of the bank is sufficient for one hour's production of body shells. It is required in order that the Bonderizing plant can be held empty of bodies during the mid-shift meal break.

Automatic body painting

The paint shop occupies part of the first floor of the new building, and is separated from the trim shop on the same level by a fire wall. The area covered is approximately 91,125 ft² and above it is a pent house with a floor area of 83,531 ft² in which drying and stoving ovens and the air-replacement and ventilation plants are installed. The paint shop is virtually divided into two main sections, one dealing with the body shell and the other with sheet metal panels and smaller components which are assembled to the vehicle at later stages. Dealing first with the body painting line, the pre-paint operations include cleaning by hand, followed by the spray Bonderizing process, and phosphate etching which also provides a key for the paint. Entering the phosphate tunnel, the body receives a hot alkaline rinse at 150-180 deg F, followed by two warm water rinses. It then enters the Bonderite section and is coated inside and out by high pressure sprays. A chromic acid solution is also sprayed automatically to complete the process. The operation is ended by draining off and then drying off the body in an oven.

The body is then transferred by hoist to the paint conveyor. At this stage it is sealed at all necessary points above the dip line by means of a thermo-plastic sealant applied by pressure guns. This material sets hard when the body is in the stoving oven following subsequent operations.

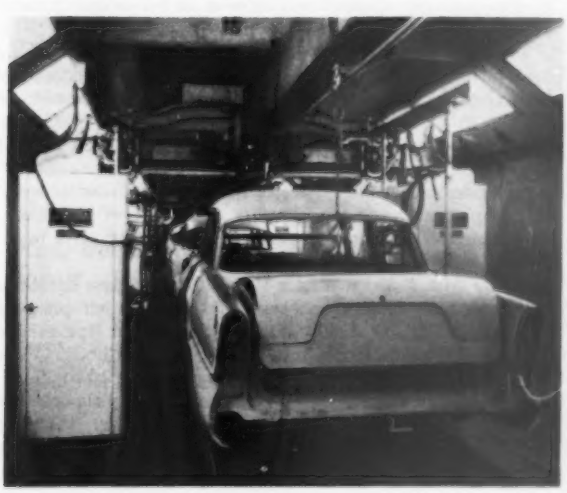
Underbody dip

A coat of special synthetic paint is applied all over the inside and undersides of the floor of the body. The paint also passes through holes, provided for the purpose, in the boxed sections of the structure. A tank holds approximately 2,000 gallons of this paint and in this the body is dipped to a minimum depth of 12 in. The paint blends perfectly with the red oxide primer surfacer coats, which are applied in the next operation.

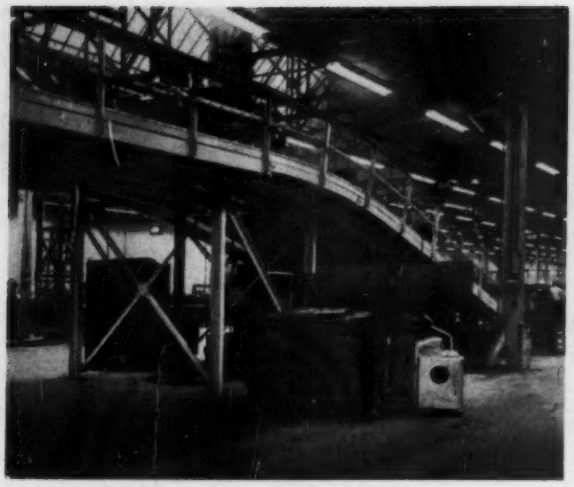
Primer surfacer

Red oxide primer surfacer—two double coats, wet on

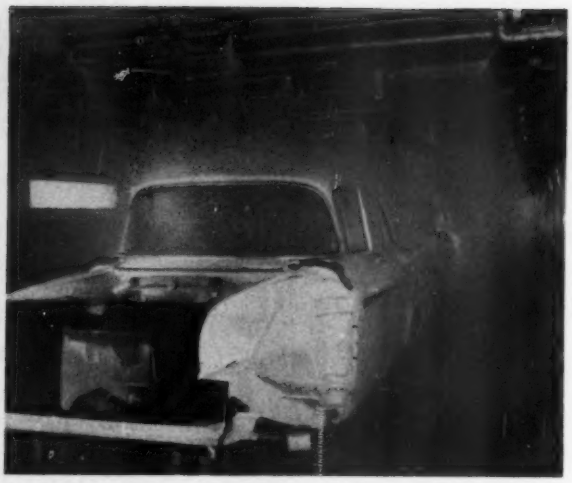
Schweitzer automatic painting machines in primer surfacer booth



Carrier double-tracked stoving oven for body primer surfacer



The assembly line is raised in a "flyover" to provide passage for the battery-electric distribution trucks



Finished body shells passing through the water-test tunnel to check weather-proofing

wet—is applied by automatic spraying machines in a Carrier double-sided spray booth of the water-washed exhaust type, 120 ft long by 16 ft wide. The booth is lit from behind wired glass panels by banks of fluorescent tubes. Two Carrier-Schweitzer automatic spray machines are installed to ensure adequate film thickness at maximum production rates. Each unit is complete in itself and carries spray guns which reciprocate and follow the contours of the body so that the angle of spray, distance, and the speed of application are automatically adjusted during the operation to ensure an even film of paint over the whole surface of the body.

The equipment is controlled by three sets of infra-red beams working in conjunction with photo-electric cells. As a body approaches the machine, it first cuts the control beam for the two side units and causes the gun arms to reciprocate, the paint to be turned on and, at the end of the run, the paint supply to be turned off. The side machine guns paint from the underside of the body to the waist line. When the body cuts the second beam, the two top units start to reciprocate in a similar manner. The breaking of the third beam causes the top unit guns to be raised from their lower spraying position over the bonnet in order to spray the roof, and the restoration of that beam lowers the guns again to spray the luggage trunk lid.

All spraying units are equipped with "cut-off" controls so that the start and finish of the stroke of the gun can be set to within an inch of the edge of the surface being painted. This conserves paint by the avoidance of overspray. The machines are designed to apply an even-thickness coating over constantly changing contours and can readily be set to meet special requirements. For example, after a body has been slipper dipped it is necessary for the thickness of the primer coat to be reduced as it passes over the dipped area, in order to avoid a ridge line. Such operations can be easily accomplished by these machines.

Spray machines are interlocked with the conveyor so that a conveyor stoppage automatically stops the painting operations. The restarting of the conveyor causes the painting operation to immediately restart and continue without detriment to the finish of the work. Machines are arranged so that colour changes can be rapidly made between bodies on the conveyor and thus any loss of production is avoided.

On passing out of the spray booth, the body traverses a flash-off tunnel, which connects the booth on the first floor to the primer surfacer stoving oven in the penthouse above. This double-tracked oven is heated by steam through heater batteries serving air through a duct system with high-velocity nozzle outlets. A temperature of 300 deg F is maintained and the stoving time is 38 minutes. On return to the paint shop floor the body enters the underbody sealing section, where a bituminous compound is sprayed on the underside of the shell by a Schweitzer machine and by hand. This compound dries off during the next operation, which is wet-sanding with both vibrating and rotary tools and also by hand methods. It is then washed in warm water and drains off as it travels up to a drying oven in the penthouse, in which the time occupied is about 14 minutes.

Returning to the paint shop again, the bodies traverse another Carrier booth for the spot spraying of edges and other details. A continuation of this booth is the sealer tunnel where compound is applied by pressure gun around floor sections and joints. Next the body goes through the Tac Rag enclosure, which is also equipped with vacuum cleaning plant so that the body may be prepared for the colour spray.

The monotone colour booth is similar to the primer surfacer booth, but is 150 ft long and is supplied with filtered and tempered air of correct humidity. In it are three Carrier-Schweitzer spray machines, spaced so that hand spray touching-in can be applied between coats. Two double coats are applied, wet-on-wet, and a colour change-over can be made in less than a minute.

The body ascends to the penthouse by way of a warmed-air flash-off tunnel to the stoving oven, which is served by high-pressure hot water to maintain an air temperature of 180 deg F. The baking time is 28 to 30 minutes. The body is then returned to the paint shop floor. In the case of two-colour models, they are transferred to a separate conveyor and the processes repeated in another and similar range of equipment, having a capacity half that of the main, monotone, plant. Finally, the body is mounted on a floor-level conveyor for transfer to the trim shop.

In the trim shop, at a later stage after the glass has been fitted, the body undergoes a severe test for weather-proofing in a tunnel where finely divided cold water sprays are directed at various angles to all surfaces of the body. Four different water pressures are used ranging from 10 to 25 in^2. An operator travels in each body, examines and reports any leakage, and immediate rectification is made. Another opportunity to check weather-proofing occurs when the vehicle is road tested before passing out for delivery.

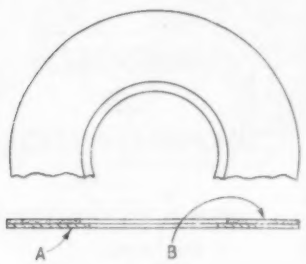
CURRENT PATENTS

A REVIEW OF RECENT AUTOMOBILE SPECIFICATIONS

Graphite-faced clutch plates

Substantial advantages are advanced in this invention for the use of graphite as a friction facing for clutch plates; in particular for the plates of multi-disc clutches. In the quoted example the plate A is of steel and the facing B, substantially covering at least one side of the plate, consists wholly of pressed graphite. Attachment of the facing to the plate is by means of an adhesive, "Araldite" being used in the example referred to and is stated to ensure a permanent bond under all circumstances.

The coefficient of friction of graphite is higher than the coefficient of adhesion and, consequently, the clutch plates have a vibration-damping characteristic and the clutch will not chatter when violently disengaged. Due to the high melting point of graphite—several thousands of degrees C—the facing is unaffected by temperature changes in operation. Frictional heat developed on slip of the clutch is effectively carried away as the thermal conductivity of graphite is about thirty times that of carbon.



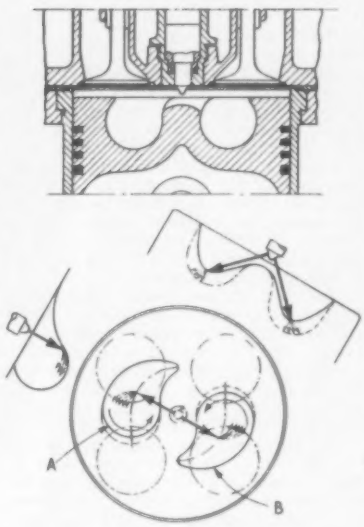
No. 794939

Friction and adhesion coefficients of pressed graphite are high, even under the influence of a lubricant, and there is a high specific clutching or braking capacity coupled with a low-rate abrasion of the friction surface. As a consequence, it becomes possible to reduce the friction area by about one-seventh in comparison with conventional components, permitting more compact clutch designs giving reduction in dimensions and weight.

Material abraded from the friction facing is capable of acting as a lubricant and will be innocuous if passed into the lubricating oil. The scope of the invention includes the facing of conical clutches. *Patent No.* 794939. *Daimler-Benz A. G.* (*Germany*).

Multi-chambered piston for diesel engine

With the object of effecting a thorough division of the fuel in the air charge, this piston is formed with a plurality of vortex chambers in the crown. The axes of the chambers are arranged uniformly around, and parallel to, the axis of the multi-hole injection nozzle which sprays fuel directly into each chamber. In the four-valve cylinder shown, the injector is mounted vertically on the cylinder axis and the piston has two diametrically opposite chambers.

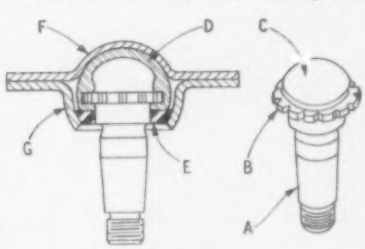


No. 793084

Each chamber A is substantially spherical in shape, with a tapering trough B disposed on the pitch circle of the chambers and giving in plan a pear-shaped configuration. Fuel is injected at an angle of approximately 45 deg to impinge on and spread over an inclined portion of the chamber wall. It is entrained by the air displaced from the cylinder during the compression stroke and swirled around the axis of the chamber, ensuring thorough mixing. By the provision of two or more chambers, fuel and combustion gases are distributed substantially over the entire cross section of the cylinder. *Patent No.* 793084. *Daimler-Benz A.G.* (*Germany*).

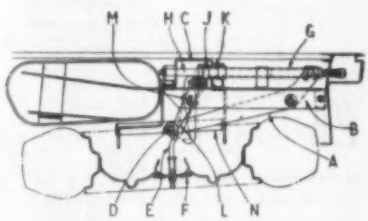
Ball and socket assembly

Intended primarily for steering linkages, this assembly is more simple and less costly to produce than the conventional highly finished metal ball stud and socket. The stud A is formed with a flange B, notched on its periphery, and an oblate protuberance C. Over these details is moulded a ball D of a relatively tough, high impact strength, fibre-reinforced, non-metallic material, such as nylon, polytetrafluoroethylene, or urea resins. A lubricant, such as molybdenum disulphide, may be contained in the material. Both the flange B and the head part C may be left as formed or cast, without subsequent machining. The head is so shaped that the moulded material forms a layer of approximately constant thickness, and the notched flange ensures that the ball is securely keyed in position. If desired, the surface of the ball may be grooved for the distribution of lubricant.



No. 794611

A separate annular seal E of a lubricant-resistant material, either the resins used for the ball or a synthetic rubber, fits snugly around the shank of the stud and has a part-spherical external surface that is concentric with, but of larger diameter than, the moulded ball. The socket comprises complementary upper and lower parts F and G, each formed with part-spherical depressions. On assembly these parts are secured together and the space between part G and ball D is packed with lubricant. *Patent No.* 794611. *General Motors Corporation* (*U.S.A.*)



No. 793306

Spare wheel carrier

Primarily intended for commercial vehicles, this carrier elevates, supports, and lowers the spare wheel by mechanical means manually operated by a conventional wheelbrace. The lifting lever A is pivotally mounted on a support bracket B secured to cross member C at the rear of the chassis frame. At the end of its longer arm the lever has a rod D over which is engaged a hook E adjustable in a centering plate F, spring-clipped in the bore of the wheel body.

Profiled slots in the end of the shorter arm of the lever are engaged on the trunnions of an internally threaded block and sleeve assembly G. The sleeve, slidably supported in a bracket on the rear of cross member C, houses a rod H which is screwed at the rear end to engage the trunnion block and at its forward end is rotatably supported in a bracket on the front of member C. A wheelbrace inserted through an orifice in the body panel can engage a hexagon on the screwed end of the rod.

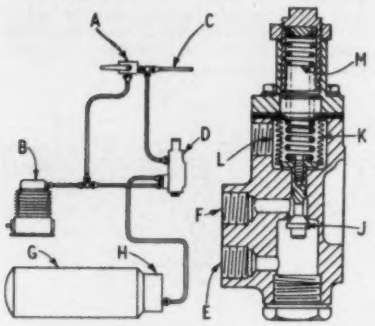
To the front end of the sleeve is secured a stop collar. Intermediate this collar and the sleeve support bracket on the rear of the cross member, is a slidable clamp bracket J, constrained by spring K. On bracket J is pivotally suspended the hooked clamp L which rocks about pin M in bracket B to engage rod D at the end of the lifting lever.

In operation, the wheel is pushed under the rear of the vehicle and hooked to the end of the lifting lever. Rod H is then

rotated by the wheelbrace, causing assembly G to move rearwards and raise the lifting lever and the wheel until the rim seats on location brackets N on the underside of cross member C. Continued rotation of rod H maintains support for the wheel while the stop collar on the sleeve moves the clamp bracket J against its spring to latch the clamp L on rod D. The weight of the wheel is transferred from lever A to clamp L and the wheel is secured tightly against brackets N. *Patent No.* 793306. *Ford Motor Co. Ltd.*

Tyre inflation

On goods or passenger vehicles equipped with a compressed air system, as for braking or door operation, the supply is also employed for tyre inflation. However, this operation can become unduly extended by the functioning of the customary unloader valve between the compressor and the reservoir. If the required tyre pressure is higher than the cut-in pressure, initial transfer of pressure from reservoir to tyre can cause the reservoir pressure to fall below cut-in pressure. In such circumstances the unloader valve is brought into



No. 793307

operation and the completion of tyre inflation is delayed.

The provision of a three-way cock, enabling the compressor to be placed in communication either with the reservoir or with the tyre, expedites the inflation operation since it can be continued without interruption. Adoption of this method, however, involves reliance upon the operator to restore communication between compressor and reservoir when tyre inflation is completed. Neglect to do so could lead to insufficient pressure being available in the reservoir for subsequent brake operation. The valve device forming the subject of the patent eliminates that hazard.

A manually operated inflator cock A, spring loaded to the "off" position, is connected to the compressor B and has an outlet to which a flexible hose C is attached. The valve device D has an inlet E connected to the compressor, and outlet F connected to the reservoir G through the unloader valve H. Inlet and outlet communicate by way of a port controlled by a poppet valve J, the stem of which is secured to the base of a metallic bellows K housed in chamber L in continuous communication with the outlet of cock A. The bellows is thus subjected to the pressure obtaining at the cock outlet and in opposition to this pressure is a spring M, adjustable by means of its screwed retainer, tending to raise the valve from its seating. This spring loading is set at a value considerably lower than the inflation pressure but sufficient to hold the valve off its seatings against the pressure of air flowing from the compressor to the reservoir. For example, with an inflation pressure of 100 lb/in² the spring loading could be from 25 to 30 lb/in². *Patent No.* 793307. *Clayton Dewandre Co. Ltd.*

Interlocking structural elements

It is common practice for extruded aluminium alloy panels or planks to be provided with interengaging or interlocking assembly arrangements. A simple tongue and groove is not wholly effective as a violent blow on one plank may well burst it away from its neighbours. Ideally, a dovetail joint, or one formed by a cylindrical bead and a complementary groove, is required. Planks used in the construction of commercial vehicle bodies, however, are frequently of the order of 16 to 18 feet in length and would necessitate assembly by mechanical or hydraulic means. Alternatively, interengaging parts could be made with a large tolerance and distorted to tighten after assembly.

The invention proposes a plank A having along the edge a bead B of a cross-section corresponding to a major segment of a circle. This is engaged in a groove of related cross-section in another element; in the illustration, an extruded joist C. The mouth of the groove is only slightly wider than the maximum width of the bead, measured perpendicular to the chordal flat. Thus, the bead can be inserted radially in the groove only when the plank is relatively positioned as shown at D. After insertion, the plank is pivotally turned in the groove, as indicated by the arrow, to lock the joint. The platform of a lorry may be constructed from a series of longitudinally arranged, double-beaded planks A interlocked with joists C mounted on chassis cross members E.

In a lighter construction the joists may be eliminated by the use of planks F having a bead on one edge and a groove in the other. Such planks are interlocked and laid and secured directly to the chassis cross members. At G is shown an extrusion, formed with a pair of grooves at 90 deg, which can serve as a corner connection on box vans or containers.

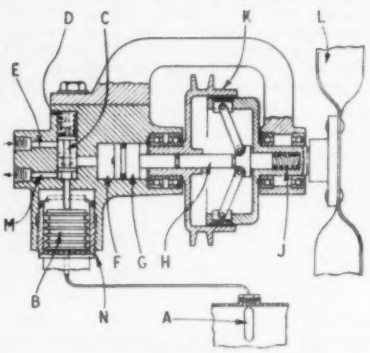
Lorry drop-sides or tailboards may be constructed from a plurality of planks secured in the interlocked position by means of the hinge straps H. *Patent No.* 794401. *Weldalloy Bodies Ltd. and P. P. Lennard.*

Thermostatically controlled fan drive

As a more complete solution of the problem of the automatic regulation of engine coolant temperature than the familiar by-pass valve, this invention proposes a thermostatically controlled fan drive. During an initial warming-up period, the fan is disconnected, shortening the period and reducing the load on the engine. The clutching mechanism is operated by fluid pressure from the engine lubrication system under the control of a thermally responsive device located in the radiator.

A pressure vessel A, filled with a fluid or gas of a type whose volume changes in response to changes in temperature, is in communication with an expansible bellows B, forming a closed circuit. When the engine coolant is cold and the bellows B is contracted, the double-spool valve C under the constraint of spring D will assume the position shown and lubricating oil under pressure will be admitted by way of inlet port E to bore F. Piston G is displaced, as shown, to operate, through plunger H, the toggle mechanism against its loading spring J and withdraw the clutch shoes from contact with the drum-shaped pulley K and disconnect the drive to fan L.

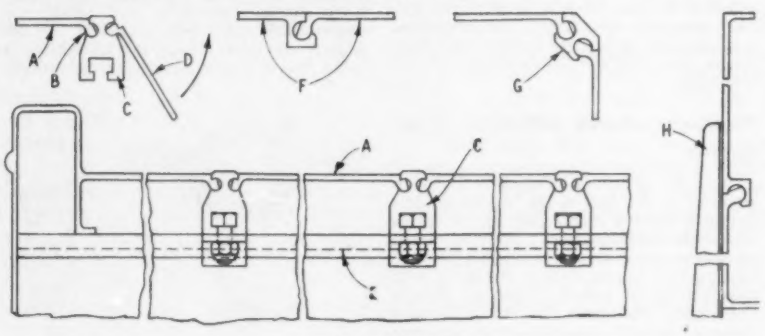
As the coolant becomes heated, the bellows B is expanded to lift the spool valve C, to cut off inlet E and vent bore F by way of outlet port M and return the oil



No. 793146

to the engine sump. Under the influence of spring J the toggle mechanism is operated to apply the shoes to the pulley drum and the drive to the fan is taken up. The proportioning of the spool valve C can be arranged to provide a substantially positive engagement and disengagement of the fan and the temperatures for cut-in and cut-out may be adjusted by regulation of the screwed housing N of the bellows B.

An alternative layout has a reversed toggle mechanism and spring J releases instead of loads the clutch shoes. However, the arrangement shown is preferred since centrifugal force developed in the shoes augments the loading pressure of spring J to ensure a slip-free drive. *Patent No.* 793146. *Borg-Warner Corporation (U.S.A.).*



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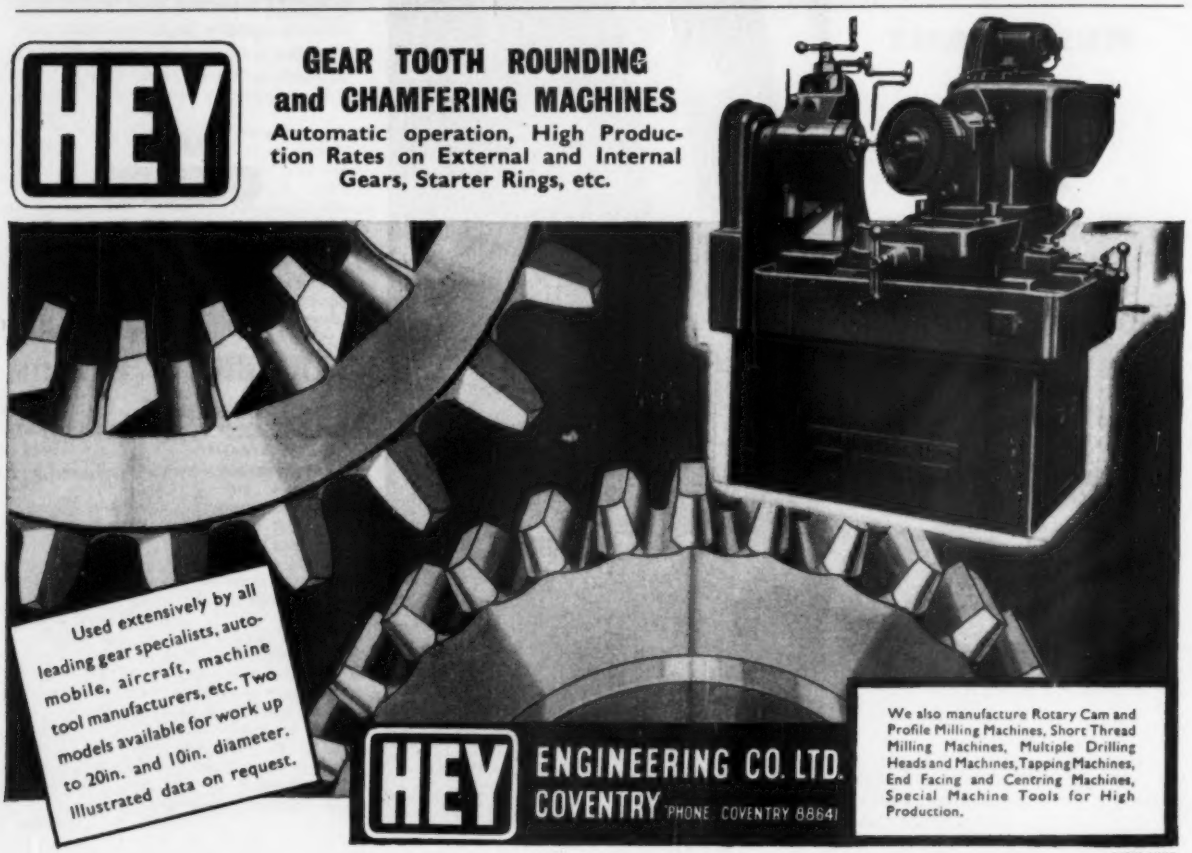
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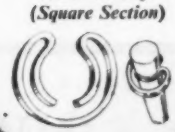

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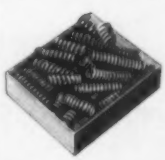

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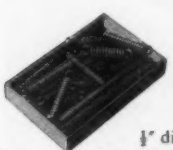

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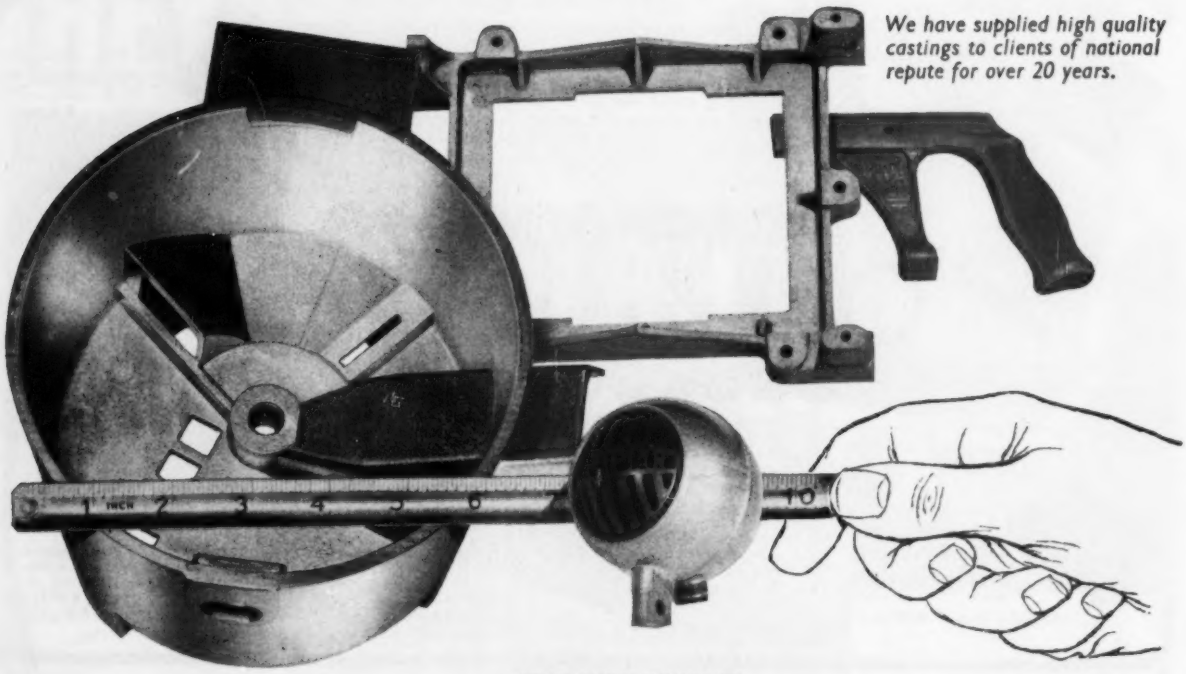

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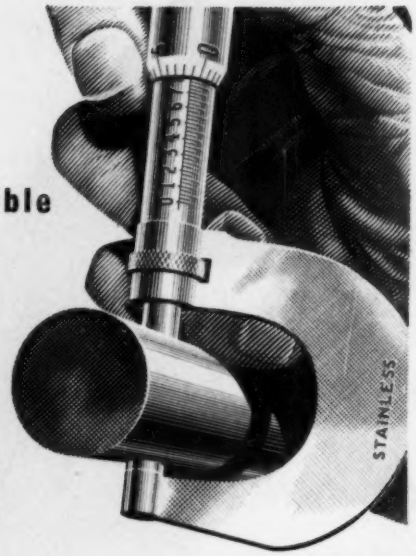
Negligible shaft wear with *these bushes



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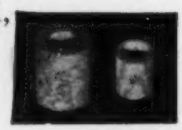

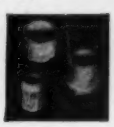

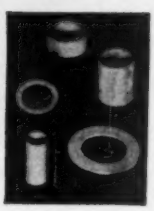

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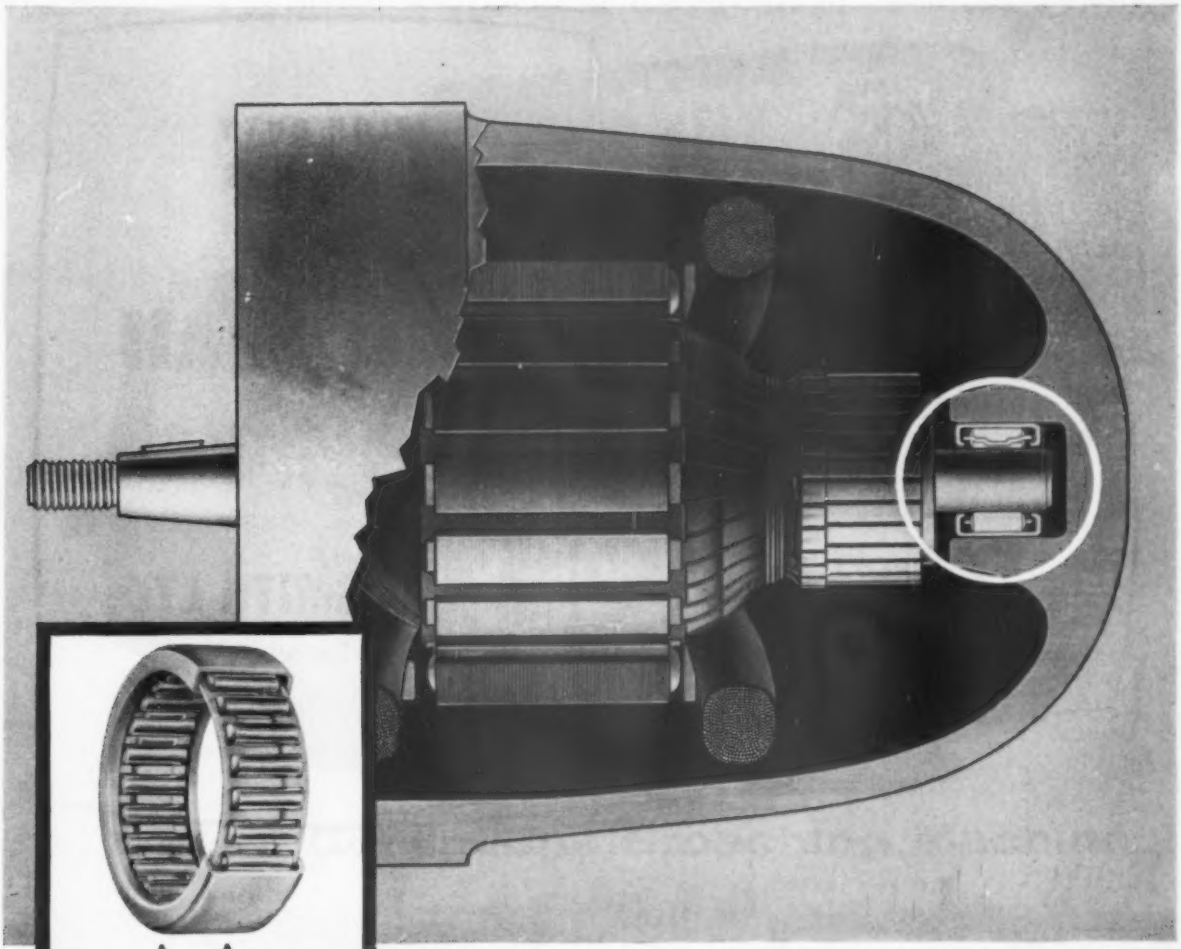

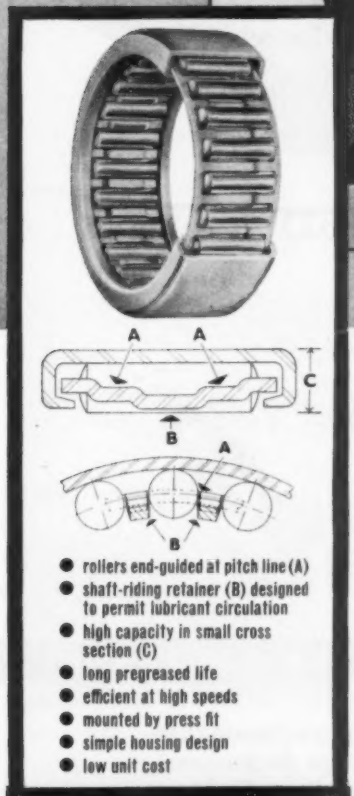

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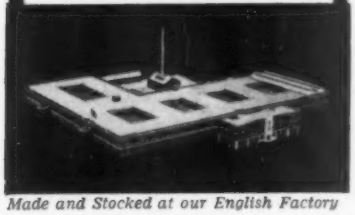

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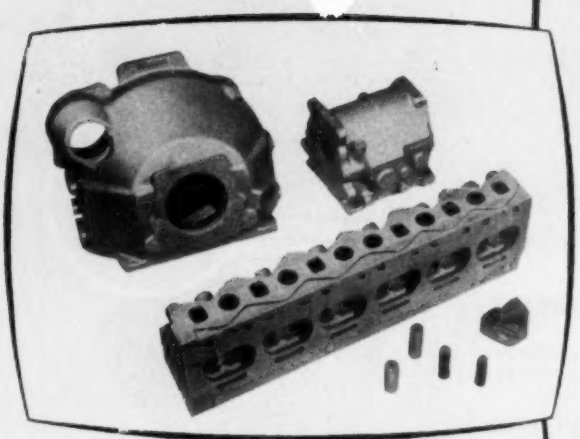

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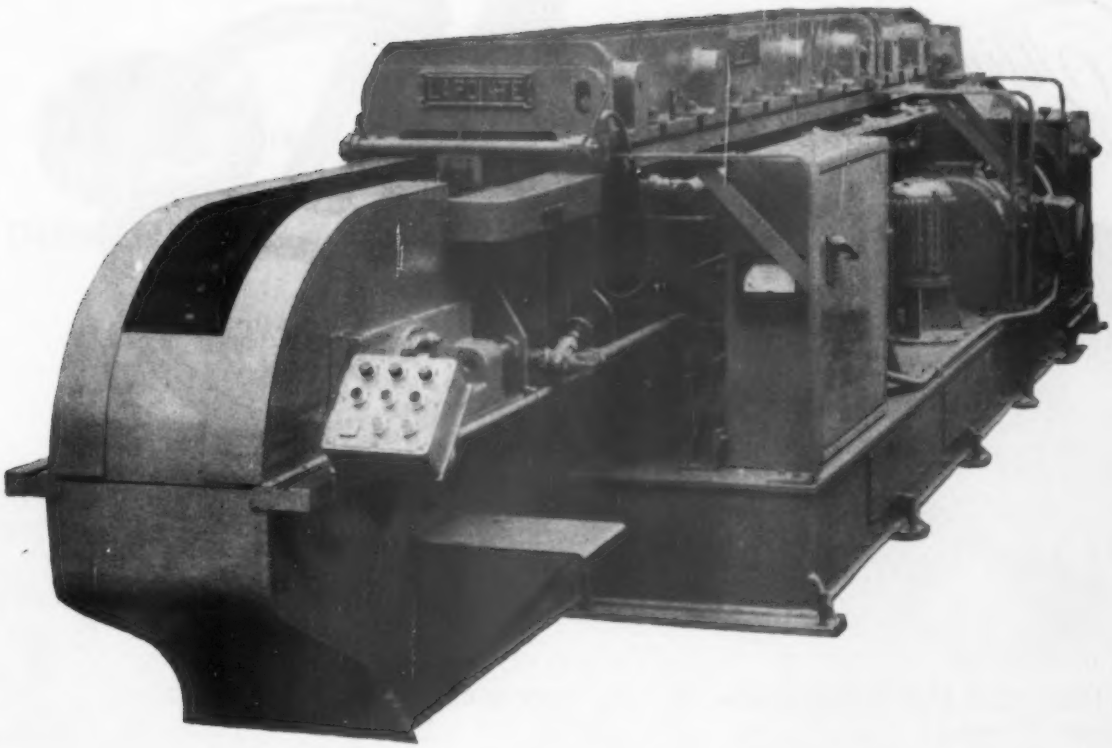

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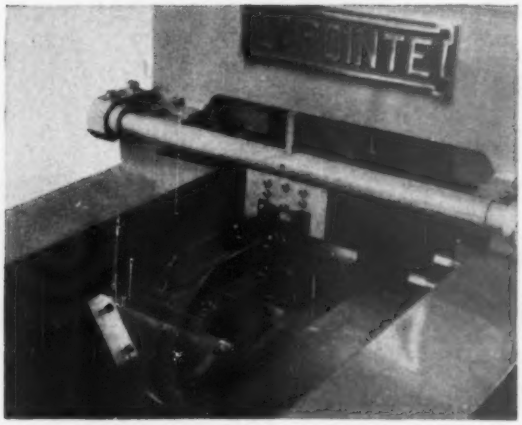

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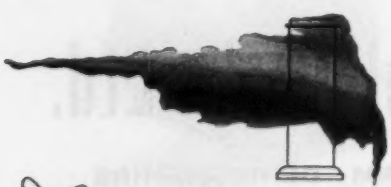

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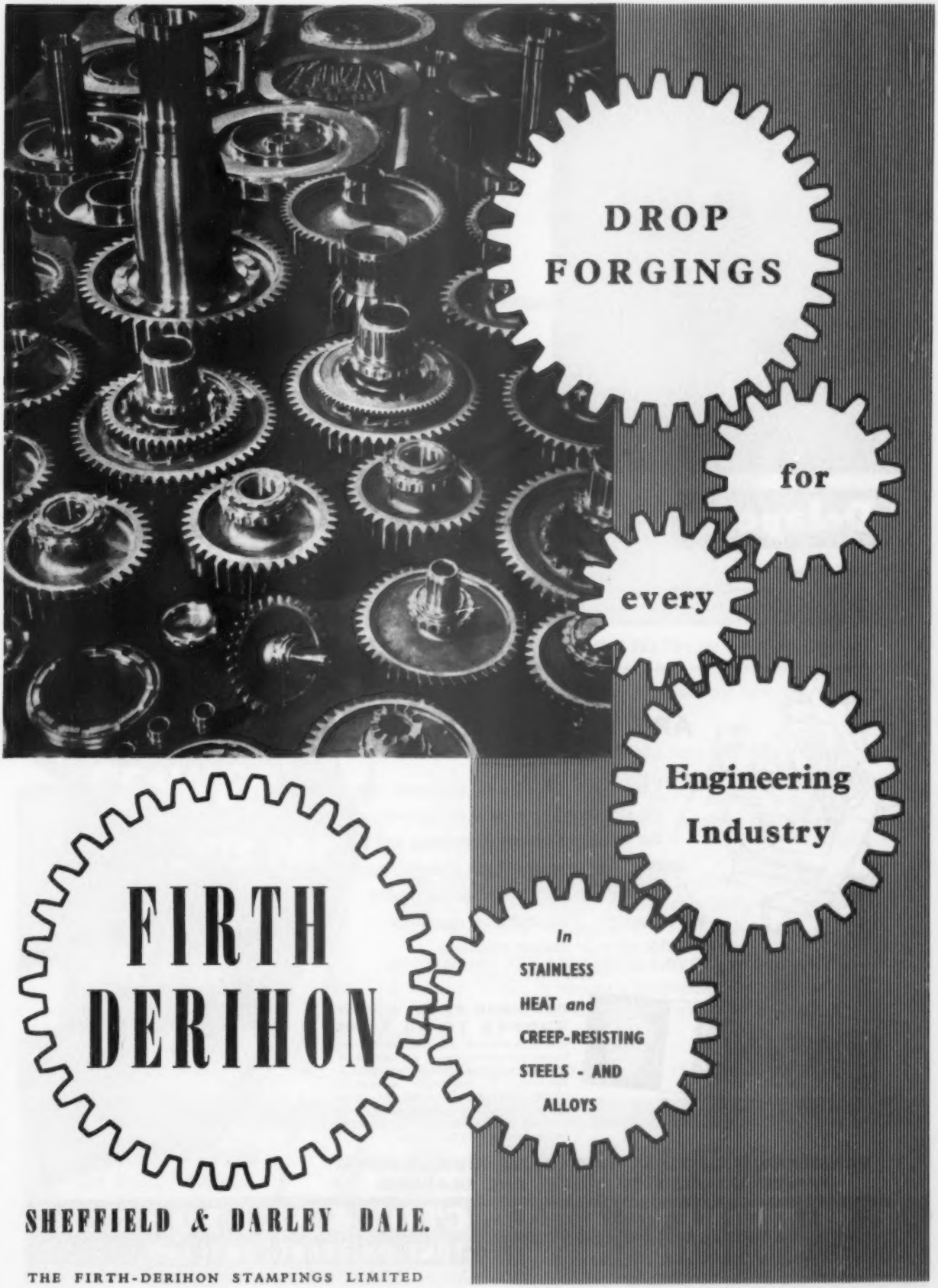
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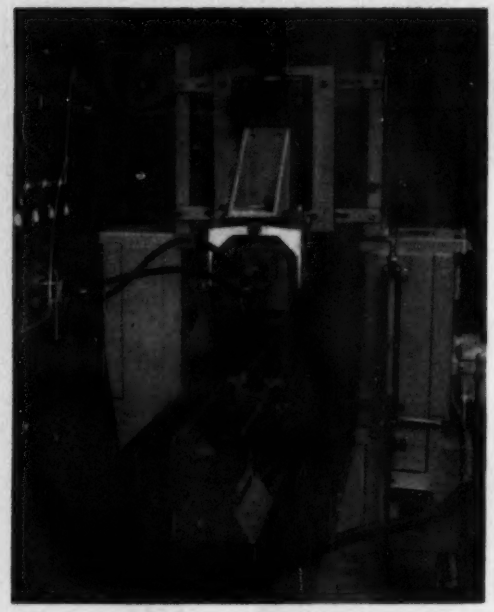

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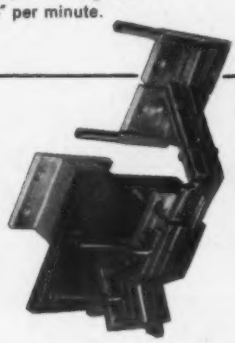

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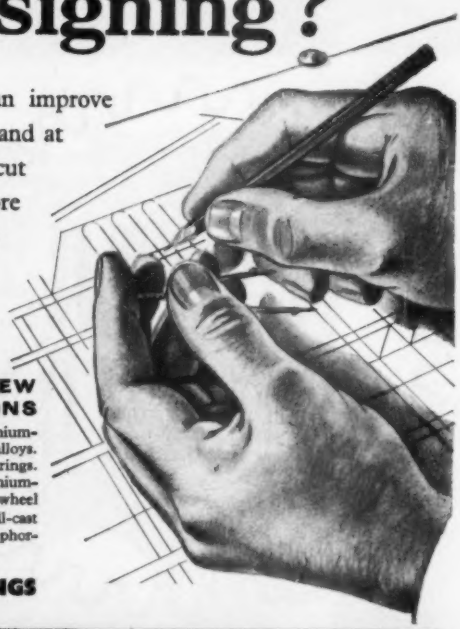

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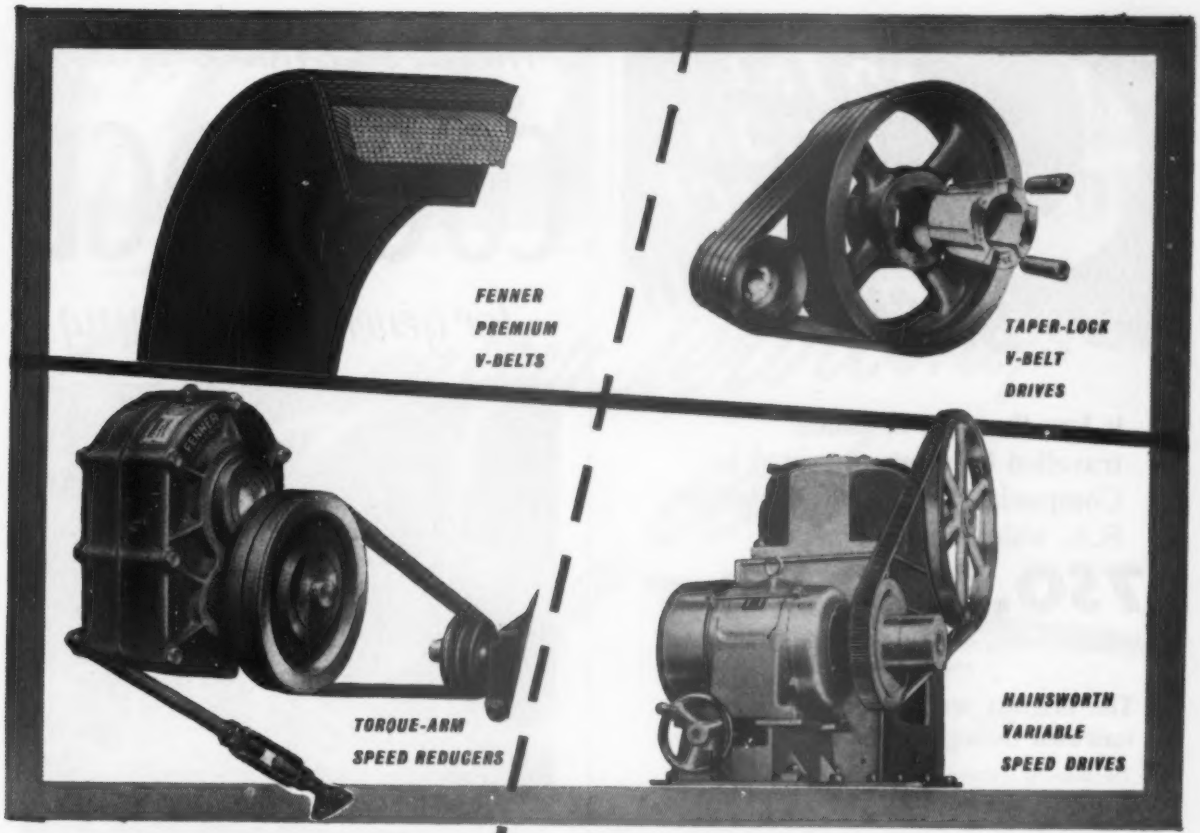

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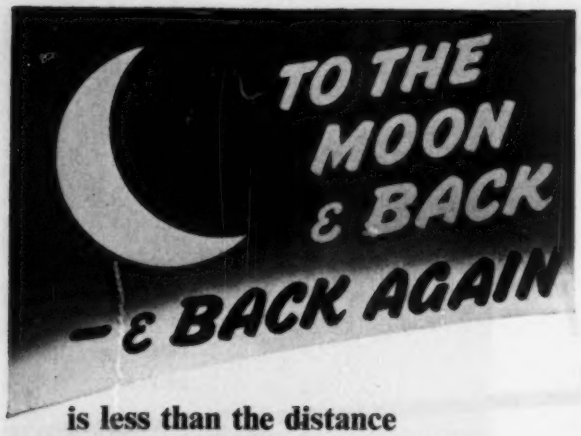

is less than the distance travelled by a bus operated by Compania Peruana de Omnibus S.A. which covered

750,000 miles

without it being found necessary to dismount the engine for repair.

The original set of Specialloid pistons was used throughout the entire distance.

The following is a translation of an Affidavit drawn up by Dr. Daniel Cespedes, Notario Publico, y de Hacienda:

COMPANIA PERUANA DE OMNIBUS S.A.

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TELEFONO 29681

APARTADO 3190
LIMA—PERU

TALLERES
AV. PROLONGACIAON CANGLLO 550
TELEFONO 36040

Herewith we wish to certify that Omnibus No. 2., of "SCANIA VABIS" make, Motor No. 62 1 79, Chassis No. 91 9 70, which operates on the Lima-Ica Line, has run 1,200,000 kilometres without it being found necessary to dismount the engine for repair.

Lima, 9th April, 1957

PERUVIAN OMNIBUS COMPANY LIMITED
J. BLUME T.
Principal of the Transport Department

The undersigned, PUBLIC NOTARY AND COMMISSIONER FOR OATHS, CERTIFIES that Mr. JUAN BLUME TRAVERSO, proving his identity with his electoral papers number six hundred fourteen thousand five hundred and ninety four and his military papers number eight hundred and seventy seven thousand six hundred and sixty two, was present in the offices of the aforesaid Public Notary, with the object of having legalised his signature in the DECLARATION which he has signed as Technical Principal of the Transport Department of the Peruvian Omnibus Company Limited, ratifying before me the said declaration which he now repeats and says as follows: "Herewith we wish to certify that Omnibus number two, of "SCANIA VABIS" make, Motor number sixty two thousand one hundred and seventy nine, Chassis number ninety one thousand nine hundred and seventy, which operates on the Lima-Ica Line, has run one million and two hundred thousand kilometres without it being found necessary to dismount the engine for repair", which he signs again in my presence, in Lima, on the thirteenth day of the month of April of the year one thousand nine hundred and fifty seven.

J. BLUME T.

DR. DANIEL CESPEDES
NOTARIO PUBLICO Y DE HACIENDA

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as original equipment

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REGISTERED TRADE MARK

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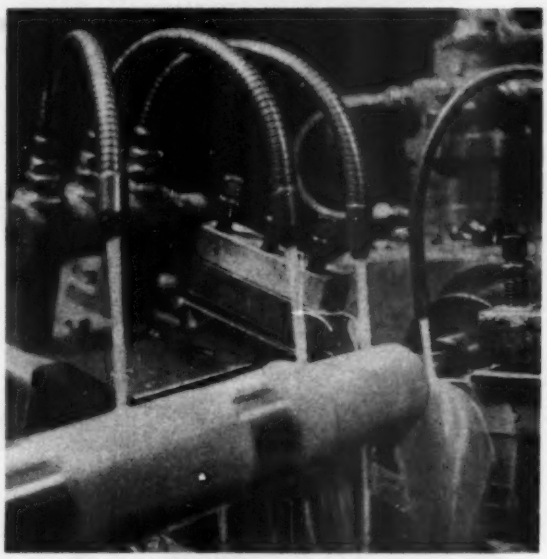

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Moreover, due to its richer, more stable emulsion, COOLEDGE can be standardised over a very wide range of tooling operations in the sure knowledge that the average tool life is extended, surface finish is held to close limits whilst a very welcome economy in emulsion strengths is achieved.

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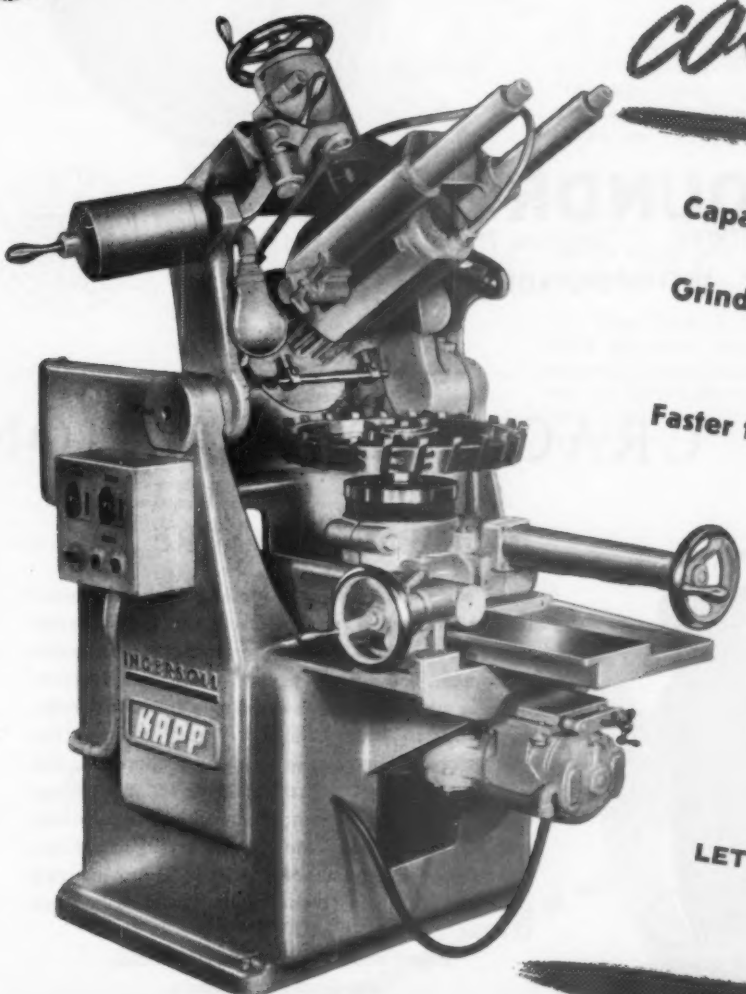

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Faster than standard grinders.

Accuracy is assured by single setting.

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The Metroflux Type "S" universal magnetic crack detector is an extremely flexible unit. It is of great value for testing components of large size or awkward shape, and for routine testing of mass-produced components.

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Even when too fine to be detected by any normal inspection method, surface cracks can be discovered immediately with Metrovick magnetic crack detection equipment. Developed primarily for tests on components produced in the company's own factories, ranging from large forgings to small pinions, this Metrovick equipment is very simple in operation. Use is made of a special magnetic fluid which, after passage of the magnetising current, enables all cracks to be seen with the unaided eye. Most requirements in industry can be met from the standard range of Metrovick crack detectors. Special equipment can, however, be made to order.

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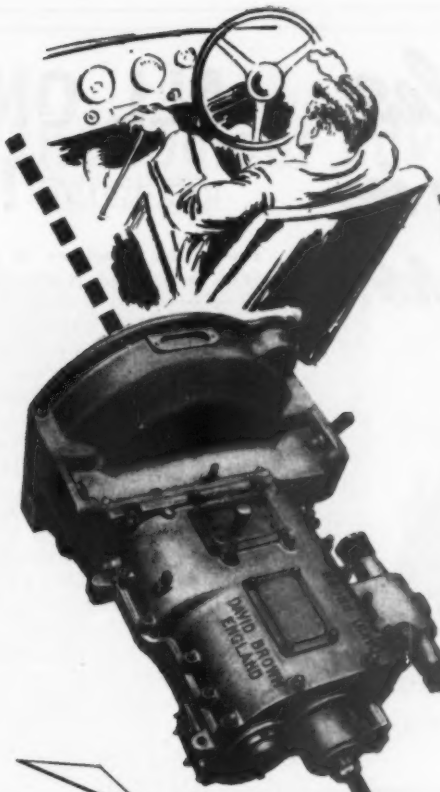

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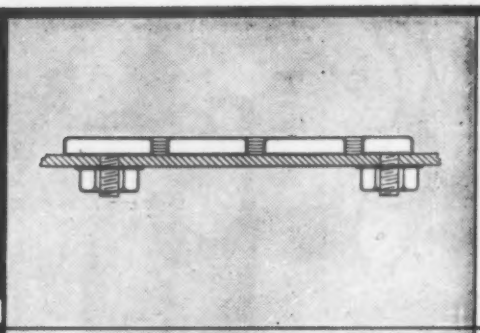
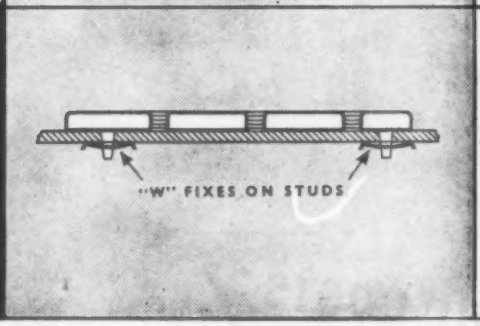


OLD WAY

Threaded studs were spot welded (or inserted if die-cast) to the name-plate. To hold this in position, washers and nuts were laboriously assembled with great difficulty especially on blind applications.



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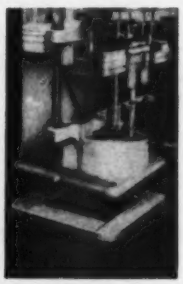

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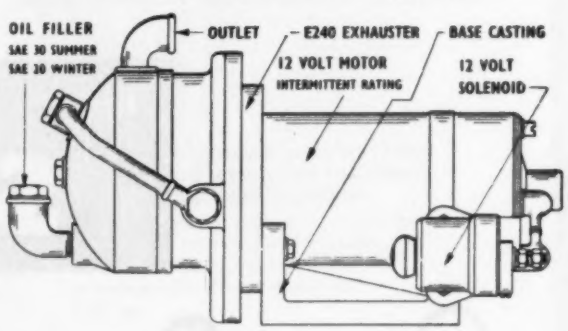

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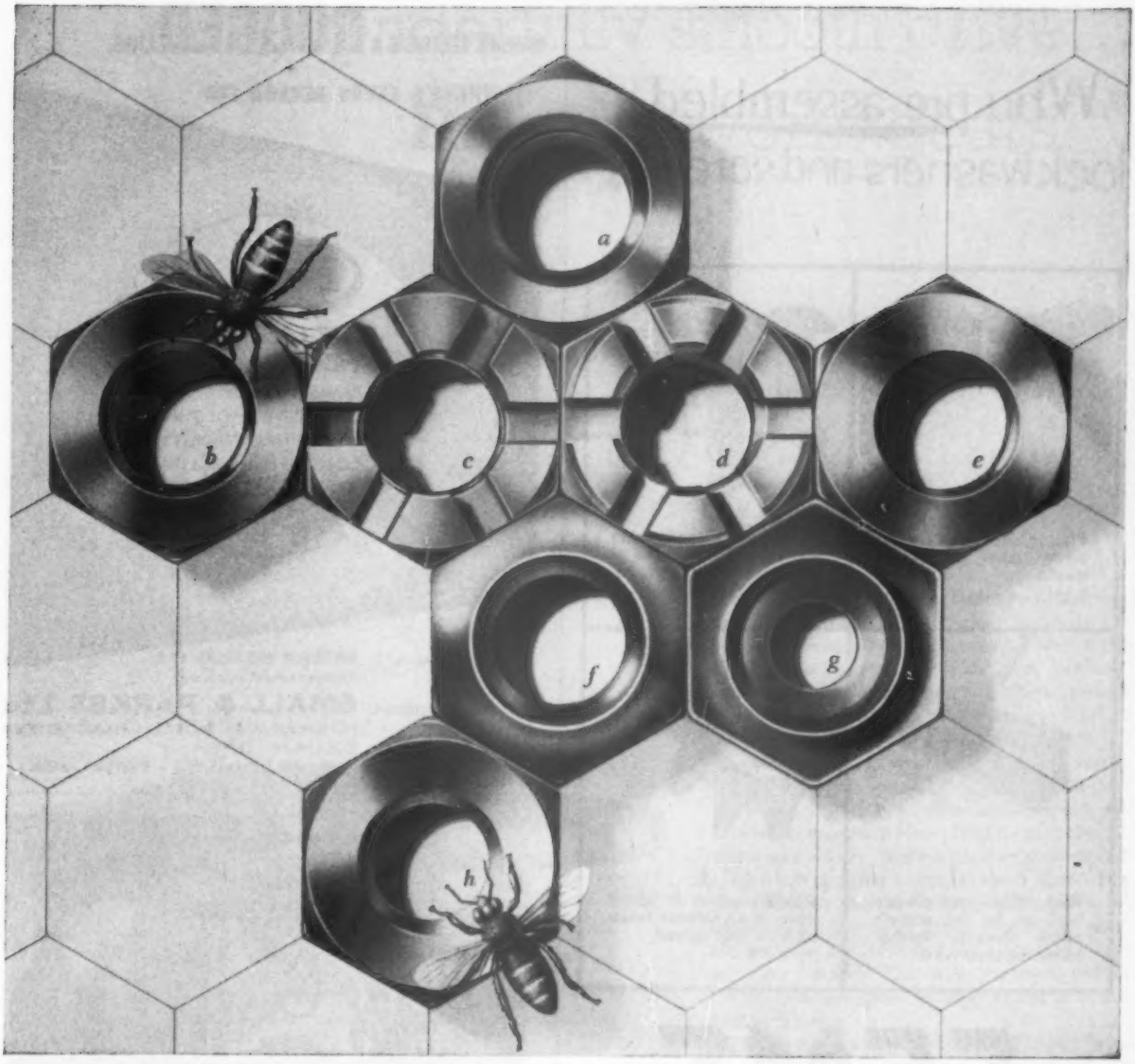

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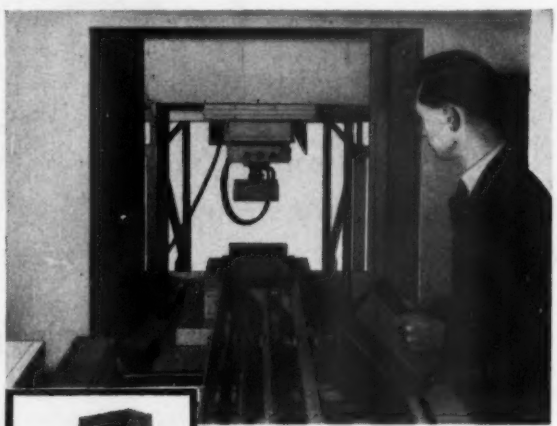

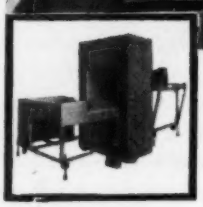

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1. LABOUR SAVING
The Unloader either replaces an Operator at back of Press or enables the front Operator to concentrate solely on feeding.

2. TIME SAVING
The Loader permits continuous feeding with the minimum of Operator movement. The two units together on a Press running at 15 r.p.m. will give a production rate of 800 per hour with one Operator. With manual loading, two Operators would do well to reach 360 per hour.

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Easy change over from one job to another. Mounted on castor wheels with built-in height adjustment, the Units can be rolled clear for toolsetting or moved to another machine and re-set within minutes.

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Relative to the savings in production costs from the use of these Units, their prices including installation, are attractive.

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Did you know that all Holroyd worm gears are made using a unique technique which gives some allowance for the inevitable deflection of bearings and gear housing? This gives improved performance with the gears working correctly in the **loaded** position.

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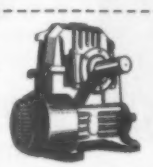
Another point—our worm gears are made, if required, right down to 1/1 ratio as an everyday product. And don't forget that these Holroyd gears will carry several times the load of straight faced spiral gears of the same dimensions, and will work with an efficiency of the order of 97 per cent.

Have a word with **Holroyd**



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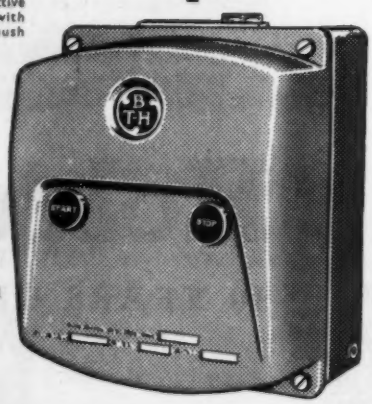
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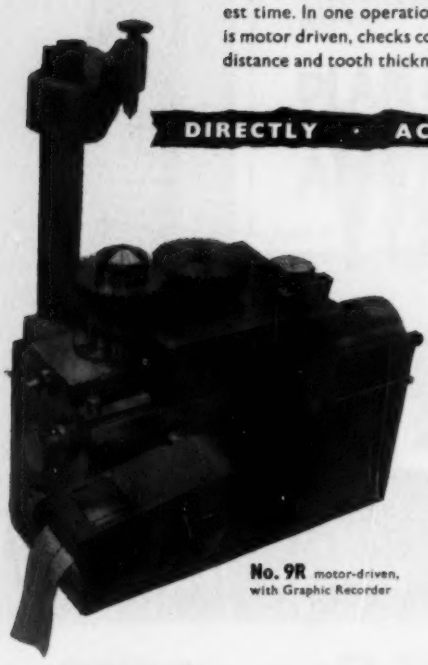

No. 9R motor-driven, with Graphic Recorder

and makes an automatic permanent record of concentricity and kick-off by means of the integral Graphic Recorder, which gives a pen trace with a magnification of 250 : 1 for spur, helical and bevel gears.

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Take the first step towards bringing your Gear Inspection up-to-date by writing for Leaflet E311.15.

THE **DAVID BROWN** CORPORATION (SALES) LIMITED
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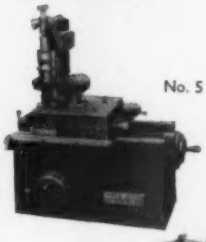

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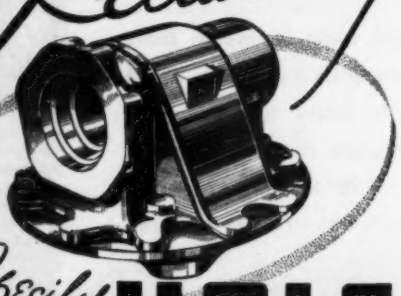

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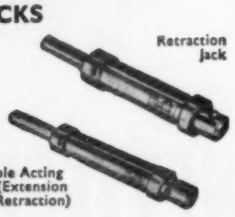

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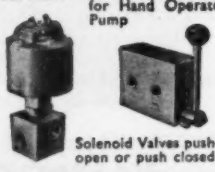

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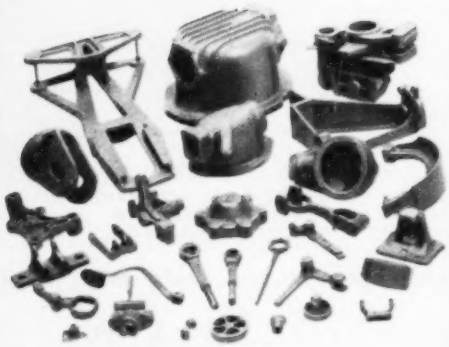

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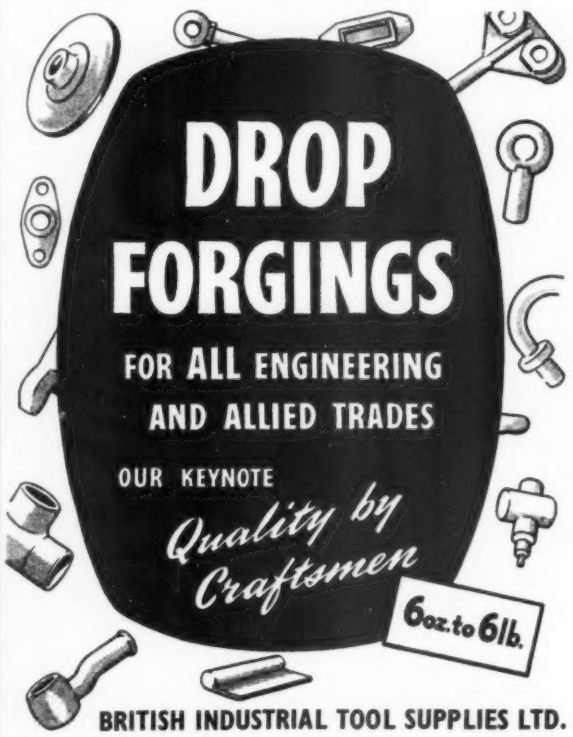

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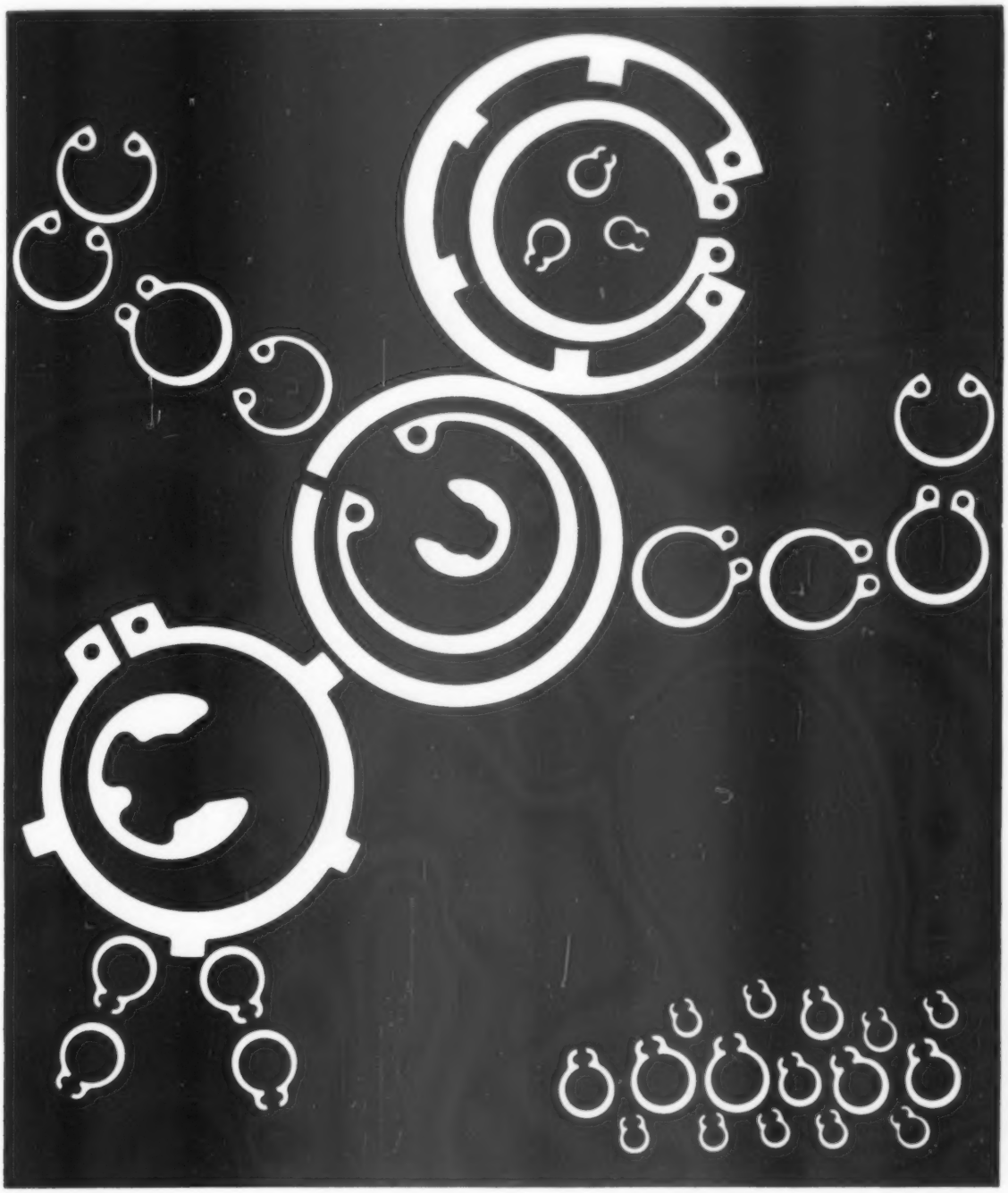

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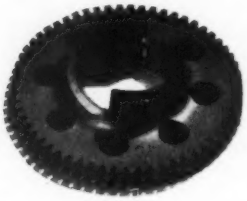
GEARS

and even more complex shapes produced without machining with DURASINT



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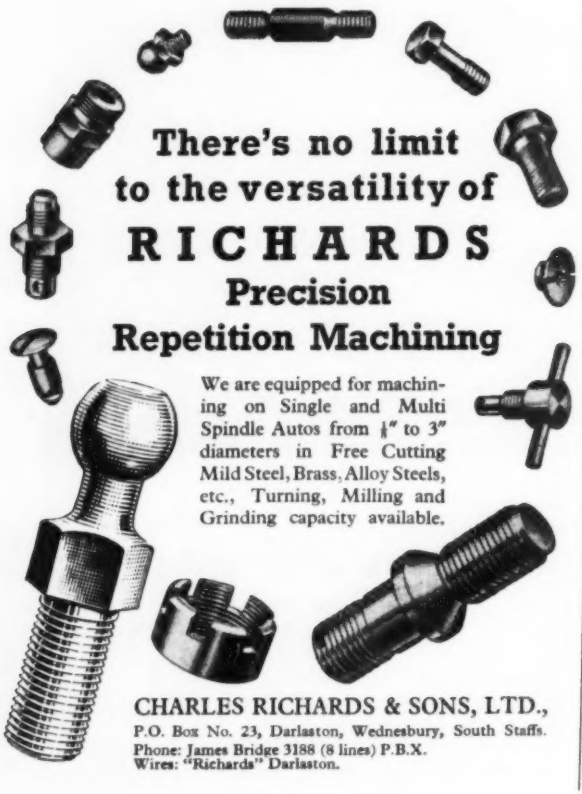

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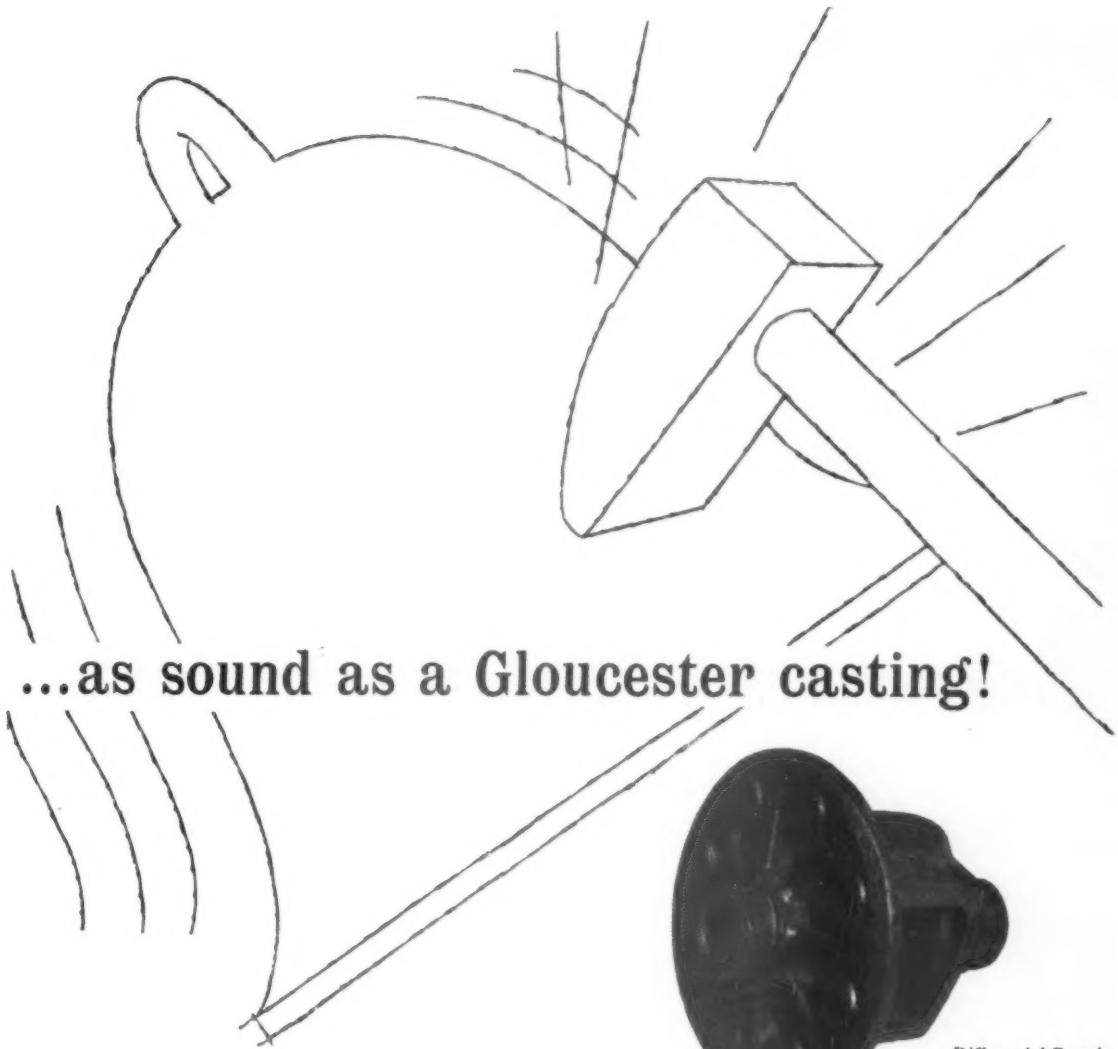

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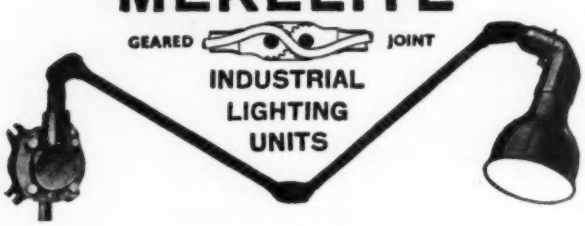

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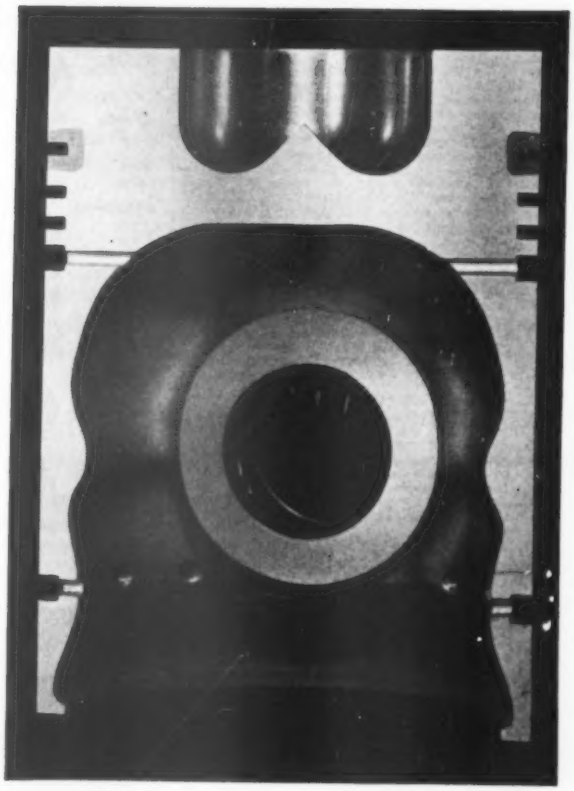

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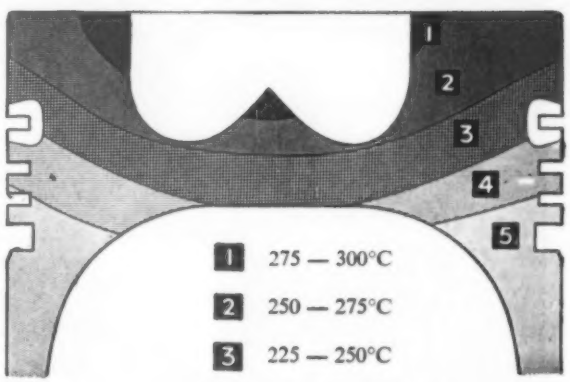

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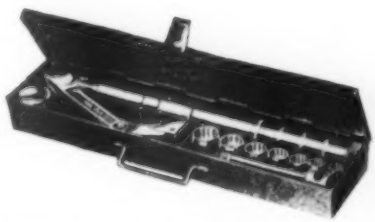

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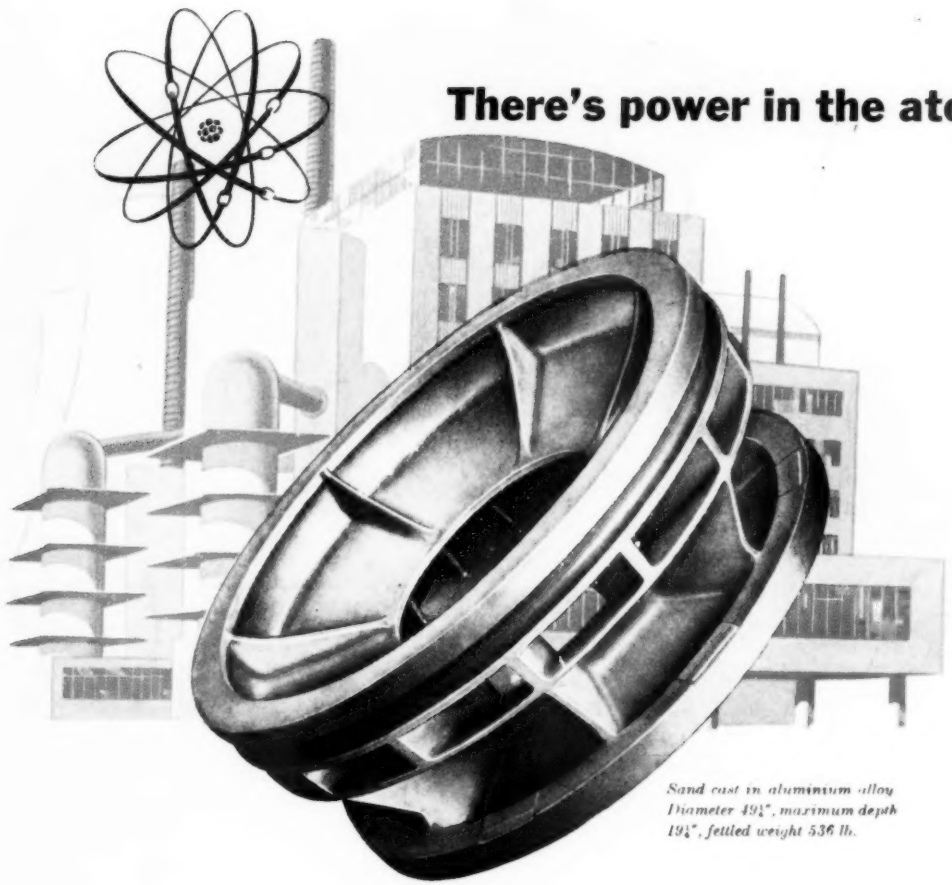

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